THE Petroleum Engineer

MIDYEAR 1934

VOLUME V NUMBER IX

THE ENGINEERING MAGAZINE OF THE OIL AND GAS INDUSTRY

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REVIEW OF OILFIELD PRODUCTION PRACTICES

By K. C. SCLATER

A GRADUAL improvement in the producing branch of the industry has been witnessed during the past year. Already there is evidence of the salutary effects of the long period of economic stress on production practice. There is no disguising the fact that operators have learned that the cost to produce a barrel of oil is, in the long run, a far more important consideration than the current number of barrels produced. It is now realized that to obtain a low lifting cost per bbl., the rate at which oil should be produced from a newly-discovered pool should be governed in large degree by the reservoir conditions rather than wholly on market requirements. If this principle were faithfully followed serious trouble from overproduction might never again be faced by the oil industry.

Great progress has been made in stripper fields and in the older producing areas in developing more efficient production methods, and there is every indication that the work of renovation and rejuvenation in these old fields will be quite extensive for some time to come.

It is not within the scope of this review to discuss even briefly all the important new developments and trends. Only those phases of oilfield practice will be covered that, while they may not be the most loudly heralded developments, probably reflect in a deeper and wider sense future progress and trends, for they concern principally practices in the fields of settled production. Three of these phases of oil field practices touched on at some length are: well-pumping practice, developments in repressuring practice, and the acid treatment of wells.

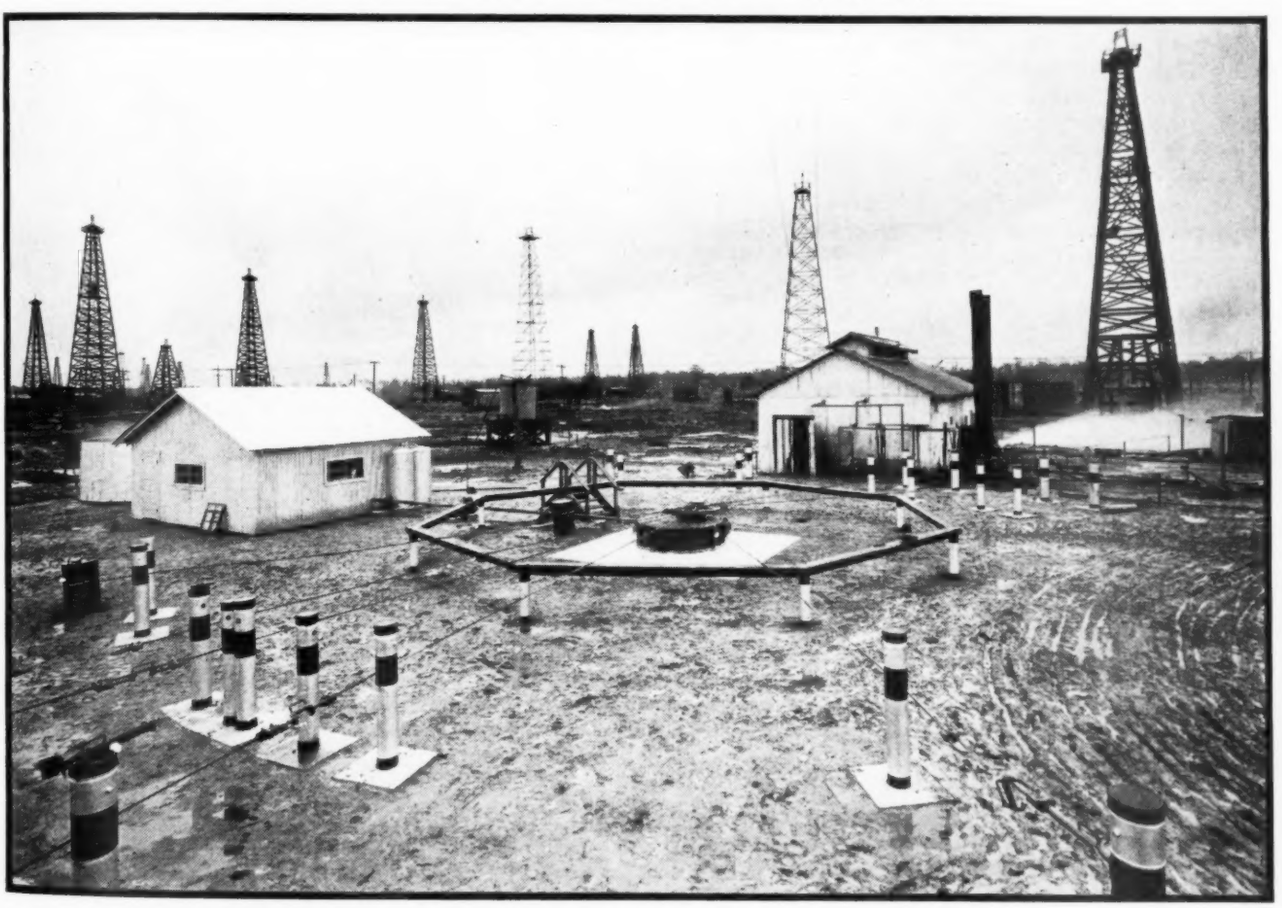
In the face of greatly curtailed production in flush fields control of flowing production becomes a necessity, but the manner of control may not be the best, being based on market requirements rather than reservoir conditions. There seems little that can be done at present to improve this situation. This phase of production practice has therefore not been emphasized in the review, despite the fact that substantial progress has been made in practices relating to the control of flowing production.

The progress in gas-lift, another important phase of production practice, is reviewed in another article appearing in this issue.

Well-Pumping Practice

Group pumping of wells from central powers is finding a

This geared power is typical of the modern trend in pumping powers



wider field of application because of the improved equipment available. Pumping powers recently placed on the market are capable of pumping deeper wells than was formerly possible and accounts for the increase in use of this type of pumping machinery.

Of the trends in design, the geared power has come into prominence. The more recent designs are equipped with helical or herring-bone gears and are of the overpull type. Gears on these units are entirely enclosed, have anti-friction bearings, are amply lubricated, and are manufactured from high-strength steels. This type of unit is well adapted to electric-motor or to multi-cylinder high-speed engine drive.

Greater refinements in measuring well loads, in the counterbalancing of wells, and in the installation of rod lines and surface equipment make it possible to balance the load on a pumping power for maximum operating efficiency. It is in these directions that the greatest improvements are taking place.

Large bandwheel pumping powers have been developed for deep-well pumping and these are now used on wells the average depth of which is greater than 3000 feet. A power of this type designed for pumping 18 such wells has a 24-ft. bandwheel, 30-in. face, and is driven by a 100-hp. twin-cylinder horizontal gas engine. Several large bandwheel powers for deep-well pumping have been installed during the past year in the East Texas field and in Louisiana.

Several central gas-engine-driven electric power plants for pumping wells by electric-motor were installed in the East Texas field. One interesting installation of this type consists of a 165-hp. twin-cylinder engine and a 125-kva. (100-kw. at 0.8 per cent power factor), 480-volt, 3-phase, 60-cycle generator, with exciter and master control panel. Power transmission lines to the wells are laid underground at a depth of about 18 inches. Each well is equipped with a triple-rated motor of 25/15/9-hp., 440 volts. The motor, of the low-starting current type, operates through a double reduction gear unit equipped with a crank counterbalance. At present the pumping well load is light and the lower rating is ample for power requirements but for pulling or for heavier loads during the later life of the well, it may be necessary to use the higher ratings. No loss in motor efficiency is incurred at the higher ratings. It will be possible to control the intermittent pumping of wells automatically by electric time switches on this installation.

Pumping jacks have undergone steady improvement. They are designed for strength and efficiency and almost all now have dust-proof, grease-packed bearings. The straight-lift feature is now embodied in the design of almost all jacks.

The benefits of slow-speed pumping are becoming more widely recognized. Proration of wells to only a fraction of their maximum producing capacity has fostered the use of slow-speed pumping methods. In deep wells, the decreased wear and tear on equipment, lower power costs (where electric power is used), and fewer pulling jobs, are reasons for the increasing trend toward this method of pumping. Paradoxical as it may seem, production has been increased on small wells by switching from high-speed to slow-speed pumping methods.

By adopting slow-speed pumping methods in the Midway field, California, it has been possible to use small electric motors varying in size from one to three horsepower. These were installed at a total cost of only $175 to $200 per well. The old motors (15/25-hp. and 15/35-hp.) on the wells were made to serve as countershafts while pumping, although still employed for pulling the well. The small motor is mounted on the large motor, the shaft of which is equipped with a sprocket or a V-belt sheave. Eventually all the small motors will have a direct drive to the bandwheel so as to eliminate the extra chain or belt now required when driving through the shaft of the large motor. It is estimated that the cost of making the change is paid out in less than a year in savings in power cost alone. Slow-speed pumping has reduced the shut-down time from 19,000 hr. to 10,000 hr. per year, or almost 50 per cent. Although the minimum pump clearance for efficient operation is .020 in. for slow-speed pumping as against .040 in. for high-speed pumping, pump wear and tear at slow speed has been greatly reduced; in addition, labor costs are lower. That this is easily possible is clear when it is considered that pumping speeds of one to two strokes per minute and motors of one to three hp. are being employed.

In South and East Texas, reducing the size of pumping motor and prolonging the pumping time on wells by changing from high-speed to slow-speed pumping, has lowered power costs. Motors of three and five hp. replaced motors of 15 and 20 hp. for pumping.

On ten wells from 2025 to 3050 ft. deep, pumping with an average length of polished rod stroke of 29.4 in. and average speed of 24 strokes per minute, the average load was 4.45 kw.; with an average length of polished rod stroke of 34.8 in. and an average speed of 7.2 strokes per minute, the average load was 1.48 kw., the power saving, at which load, (based on a rate of 14 mils per kw-hr.) was about a dollar per day per well, or 66 per cent. It should be pointed out that the 15/35-hp. motors used for high-speed pumping were operating at a low efficiency so that the saving in power cost was not entirely due to slow-speed pumping.

Several wells (seven at this writing) in the Oklahoma City field are being produced by Reda pump, an electric-driven centrifugal pump designed for deep-well pumping. Most of these have 133 stages and are rated at 97½ hp. to pump 1000 bbl. daily from 6300 feet. They are run on 2-in. upset tubing inside 7-in. casing. For handling excessive gas with the oil the pumps have a gas expeller that is reported to be successful for handling wells with a gas-oil ratio of at least as high as 500 cu. ft. per bbl. in the Oklahoma City field. On a test in a 6386-ft. well in the Oklahoma City field, a 75-hp. 126-stage Reda pump, which was run on the bottom of a 6260-ft. string of 2-in. upset tubing, the following data were gathered. The actual running time, which was not continuous on account of allowables, was about 35½ days. During the test the gas-oil ratio varied from 127 to 415 cu. ft. per bbl.; the average oil produced per 24 hr. was 785 bbl.; the power consumption 1766.12 kw-hr. per day (24 hr.); the power consumption per bbl. oil 2.25 kw-hr.; and the average power cost per bbl. oil .0225 cents. This power cost is based on a power rate of one cent per kilowatt-hour.

An individual well-pumping pneumatic unit, the first of its type in this modified form, was installed in the Van field during the past year.[1] This adaptation was anticipated in the original design. The new feature of this individual unit is that compressed air is used in the pneumatic cylinder. The compressed air system is entirely enclosed and provisions are made for heating the gas to a high temperature by the engine exhaust gases, thus eliminating the use of natural gas for heating. Controls on the system are such that steady temperatures are held. Heavily insulated lines and reasonably low pressures (210-lb.) hold down the heat and leakage losses in the system. One of these units in a larger size (10-in. pneumatic cylinder) has been in operation on a deep well in the Oklahoma City field for several months.

Rotary pumps for deep-well pumping are being investigated.[2] Rotary pumps of special design to meet the conditions found in deep oil wells are being tested. It is reported that a rotary pump with maximum rated speed of 3600

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[1] "Pneumatic Unit for Individual Well-Pumping," by K. C. Sclater, *The Petroleum Engineer*, February, 1934.

[2] "Oil-Field Rotary Pumps are Recent Developments," by R. J. S. Piggott, A.S.M.E. Meeting, Tulsa, May 14-17, 1934.

r.p.m. and a capacity of 80 gal. per min. at 1150 r.p.m. has been developed for deep well pumping.

Several wells in the Oklahoma City field are being pumped at great depth by sucker rods. One in particular is pumping with a string of ¾-in. sucker rods from a depth of 5150 ft. at an average speed of 20 strokes per min. on an 8-ft. stroke and producing 200 to 300 bbl. daily. Other wells in the field are produced by pumping from a depth of 4000 ft. or greater with ¾-in. sucker rods and without serious sucker rod trouble at high speed.

One of the most vulnerable parts of a sucker rod in deep-well pumping operations is the joint. A recent study discloses that the stress in the pin will be much higher than the stress in the rods if a high torque is used in making up the joint; also that there may be some changes in a joint after being subjected to a pulsating load.[3]

Having definite knowledge of these factors that affect the load on sucker rod joints, field men are better equipped to exercise the proper care in placing sucker rods in the well.

Important advancements have been made in the study of well-pumping problems. An investigation covering dynamometers for the study of pumping problems[4] shows that highly accurate means are available for studying stresses in a pumping well.

Developments in Repressuring Practice

In the older shallow fields repressuring practice has undergone steady improvement. This is in contrast to the larger deep fields of diversified ownership that are not long past the flush stage. Curtailment by proration in these fields has automatically brought about conservation of gas and gas energy, hence the need for embarking on a pressure maintenance program has not asserted itself. With a return to more normal conditions, however, a greater trend toward the use of gas-injection methods will probably be witnessed in these larger deep fields.

Consolidating ownership of a group of properties for purposes of repressuring has resulted in efficient oil recovery and a low recovery cost per bbl.[5] in a shallow pool in Northeastern Oklahoma. In a comparison between consolidated and unconsolidated properties in the same pool where repressuring is employed by all operators, the recovery cost per bbl. is 46.8 cents for the consolidated as against 70.2 cents for the unconsolidated properties. There are 179 wells and a total cost for improvements of $144,414 on the consolidated, compared with 153 wells and an improvement cost of $116,352 on the unconsolidated properties. The operating profit over a 7-year period, 1926 to 1933 inclusive, was $419,030 on the former and $142,128 on the latter group of leases. The operation of this group of consolidated leases, which has been described at length in previous articles that have appeared, is supervised as a unit and every advantage taken of the latest approved repressuring practices. The results to date are a strong argument for the repressuring of a pool of diversified ownership on some consolidated plan where duplication of effort and expenditures can be avoided.

Gas-air repressuring methods are extensively used in the Eastern fields, where operations continue to be conducted in an increasingly scientific manner. Experimental work is carried on jointly in laboratory and field in an effort to increase the ultimate recovery of oil. Fields that were thought to have been depleted because they have been produced over a long period of years and because old existing wells had reached a low daily rate of production are known from recent core samples to contain from 5000 to 30,000 bbl. per acre.[6] It is pointed out also that even where approved methods, such as systematic water-flooding, had been in use, core samples show that 40 to 60 per cent of the original oil content still remains in the sand.

Repressuring operations on these old Eastern fields are now guided largely by the information obtained from core samples, which are examined for permeability, saturation, and peculiarities in texture or other physical characteristics. Core examinations and analyses are made in some instances in laboratories right in the field and the information thus made immediately available to control field operations.

It is found that gas-air repressuring can be successfully applied where so-called broken sand formations exist that are not adaptable to water flooding. Under one lease, for example, the Venango sand is estimated to contain 11,000 bbl. of oil per acre, of which 3000 bbl. can be recovered by gas-air repressuring at an estimated cost of $800 per acre.

Natural gas is the most desirable for repressuring, although in the Eastern fields, where the cost of natural gas is high, air is most widely used.

Improved methods of locating key wells for injecting gas are in use. Wells are laid out in patterns similar to those used in approved water-flooding practice and based on core analyses. Only new wells are used for pressure intake wells. Wells laid out on what is known as the 4-spot (also known as the 7-spot) pattern are now believed to provide better control. On a lease where the 4-spot pattern is used each producing well is surrounded by three pressure wells, the four wells occupying an acre, while the producing wells are 180 ft. apart.

Another interesting development is the use of compound packers in pressure wells, by means of which gas can be injected at various pressures into different parts of the producing sand exposed in the well. The unproductive parts of the formation are packed off and sub-surface losses of gas or air into them prevented.

Remarkable results are being obtained by maintenance of pressure in the Quiriquire field, Venezuela, South America. This field is controlled by one company and has been under intelligent engineering supervision since the field was first developed.

Acid Treatment of Wells

The technique of applying acid treatment to wells has undergone intensive development during the past year. Improvements of the greatest importance have had to do with the treatment of dolomitic limestone wells and in the methods of determining the proper treatment in new wells. Dolomitic limestones, which are not successfully treated with cold acid, are now given an effective treatment with hot acid. The walls of the hole are first pre-heated with live steam.

Results from acid-treating show that the most important considerations in treating wells successfully are the determination of the proper blend of acid, the amount, the length of time of treatment and the subsequent analysis of the results. Although good results have been obtained in many cases where little or no preliminary study has been given to the well conditions, better and more uniform results could have been obtained by the application of scientific methods of controlling the chemical action of the acid in the well. In many wells treated there has been no means of making a proper analysis of the results obtained because of poor well records. Lack of reliable well records is one of the greatest stumbling blocks in the successful treatment of old wells with acid. Acid treatment of wells to increase production is a development of major importance.

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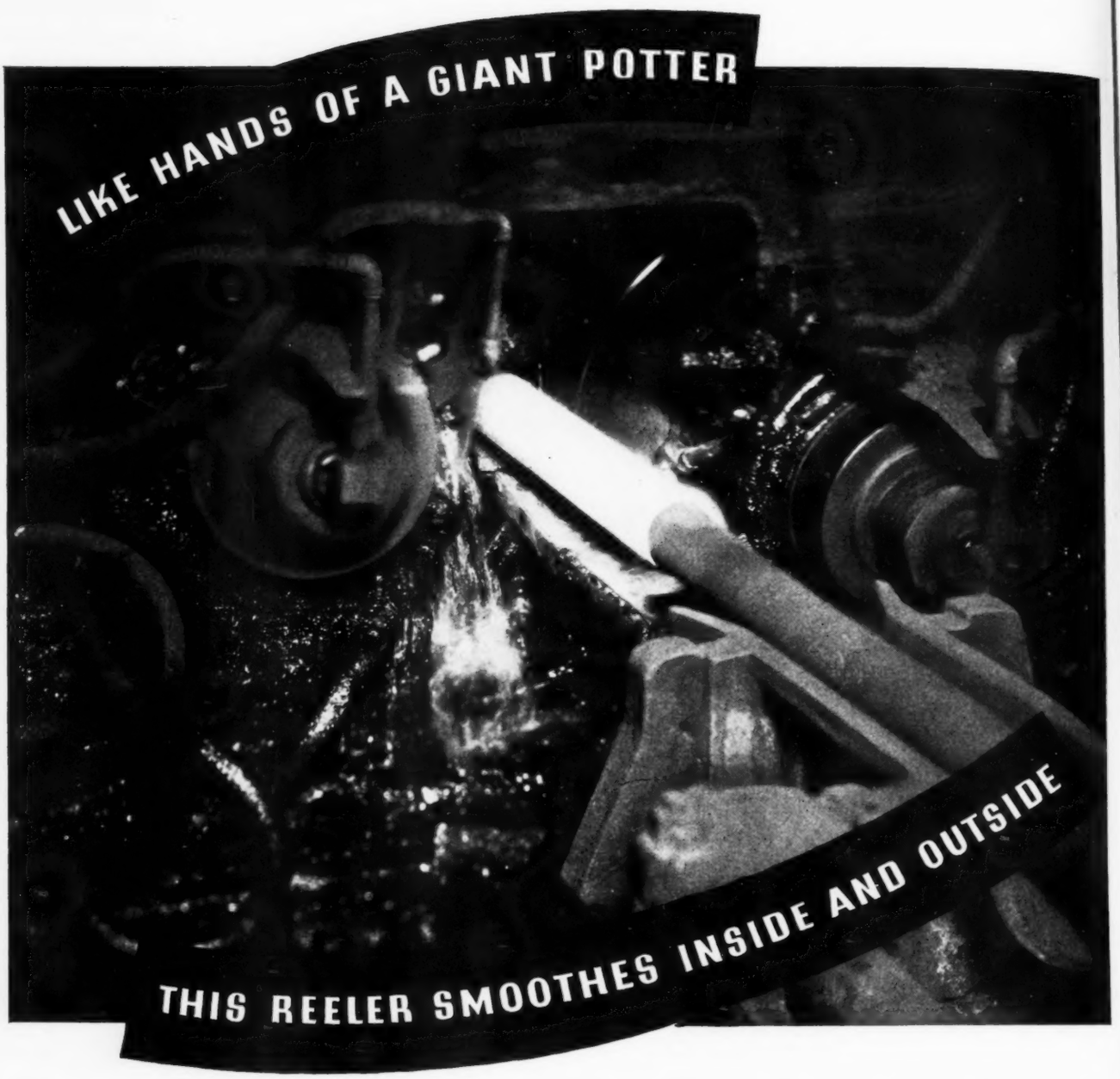
[3] "An Investigation of the Load in a Sucker Rod Joint," by Emory Kemler and L. W. Vollmer, *The Petroleum Engineer*, July, 1933.

[4] "Dynamometers for the Study of Pumping Problems," by Blaine B. Wescott, Emory N. Kemler and H. D. Collins, *The Petroleum Engineer*, May, 1934.

[5] "Advantages of Unitization in Repressuring," by James O. Lewis, A.P.I. Spring Meeting, Mid-Continent District, Division of Production, Oklahoma City, February 15-16, 1934.

[6] "Increased Recovery by Applying Air and Gas Pressure to Oil Lands," by C. C. Hogg, A.P.I. Midyear Meeting, Pittsburgh, Pa., May 22, 1934.



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Refining Industry Developments During the Past Year

By
W. L. NELSON*
Consulting Engineer

BUSINESS is said to be on the upgrade but the profits of the petroleum refiner have not been greatly increased. The present value of refined products is low compared with the price of crude oil and this has created such an unfavorable condition that few refiners can make a fair profit. This unfair price situation is not new, but by being aggravated by other harassing conditions things have arrived at such a point that something definite must be done. No industry can continue to exist if the expenses are greater than the income and the refining industry has found itself in this condition more and more frequently of late.

The government has been attempting to aid the industry by means of codes, etc., but there still remains much to be accomplished. In June of this year the gasoline production will be guided for the first time by a national coördinator. Under this plan the refiners in each district will inform the agency of their contemplated sales (and production) of gasoline during each month and the allocator for the district will allocate the district quota among the operating refineries. The impending government supervision has kept refinery managements in doubt from day to day as to just what might happen next. To some extent this has halted many operations that might otherwise have developed. Refinery managers have been further bothered by attempts to unionize refinery laborers.

Although economic uncertainty has been bothersome to refinery managements, it has not been altogether a misfortune to technical departments. Under economic stress the efficiency of operation and the development of new methods has moved forward at a great pace. Not many new processes were developed or promoted but many of the new processes of a year ago have been brought to full commercial fruitfulness.

A Competitive Industry

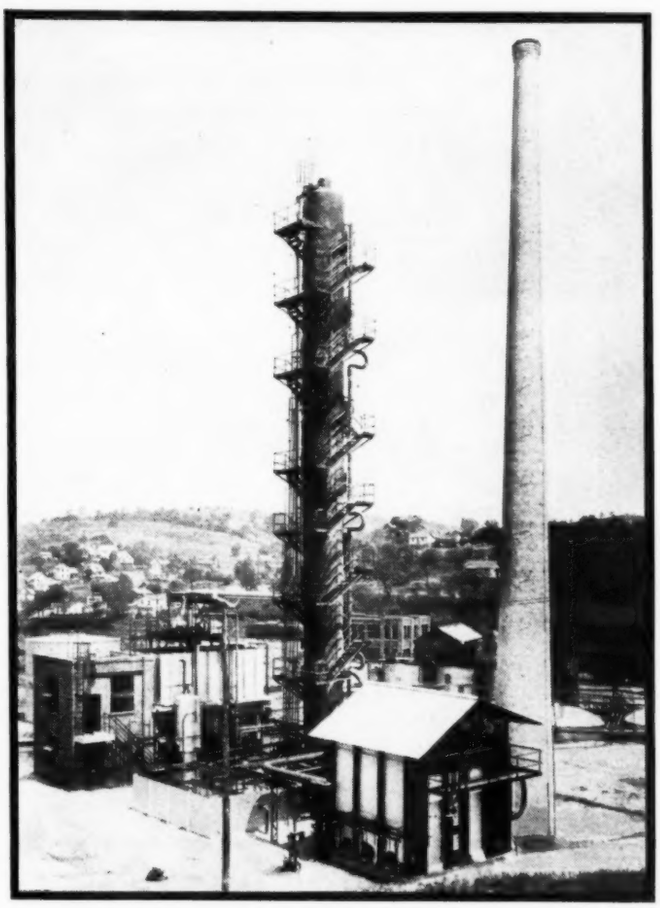
Competition in the petroleum industry has, during the last year, become so active that it threatens seriously to harm the industry. In the past the profit in the production and marketing branches has been large enough to overshadow the fact that the refineries made little profit. But in the last few years even the production and marketing branches have failed to make adequate profits and it is doubtful if profits as large as have been made will ever again be made by these branches.

In other words, the petroleum industry is rapidly changing from a stage of rapid growth to one of stable, highly competitive business. In the growth stage a certain amount of ruthless competition can be endured because even the unfortunate competitors can make some profit. But in the mature stage of stable competitive business an element of coöperation as well as competition must exist.

In many respects the recent scramble for business by means of catch phrases, pseudo technical advancements and the magnification of slight unimportant differences in products, is amusing. Some of these phases of marketing are actually destroying a part of the business that the industry already has. As an example, certain refiners have promoted the sale of sealed cans of oil and some have assured the public that the oil can be used for so many miles of service. Every technical man knows that many oils are high-mileage oils if the automotive engine is in proper condition; and yet in many cars, oil should not be used for such high mileage. The industry may soon find that the customer will use all oils for many more miles than is desirable for good engine performance and economy and the motor oil market will be seriously decreased. At the same time, the cost of manufacture will rise.

Already there is a marked trend toward the testing of used oil at the filling station to determine if it is fit for further service. If intense competition continues, a reliable method of testing used oil at the filling station may result in the use of much less oil. Even with reasonable competition the use of less oil will probably be the result.

After all, the potential market for petroleum products can be increased only by the general growth of industry and population and by opening up new fields of utilization and marketing, and fostering more intensively wider but economical consumption in existing mar-



This trim new topping plant indicates the care being given to modern refining construction details. (Courtesy Arthur G. McKee & Co.)

* Professor of Petroleum Refining, University of Tulsa.

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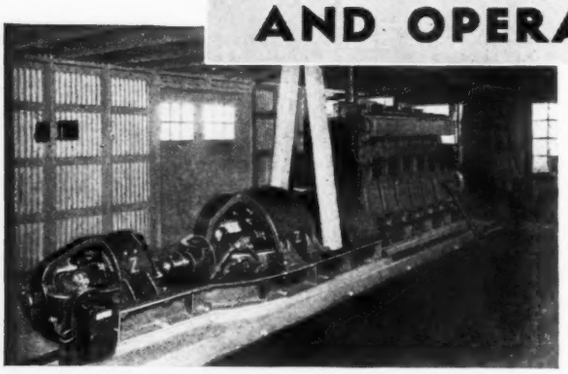
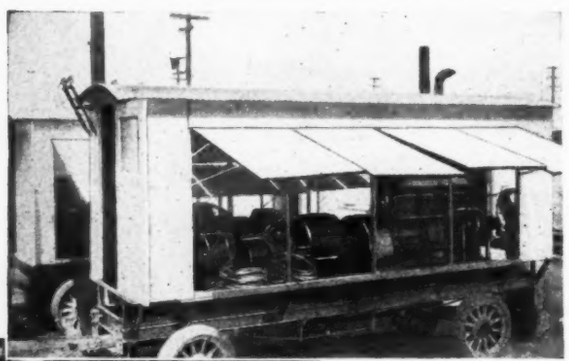
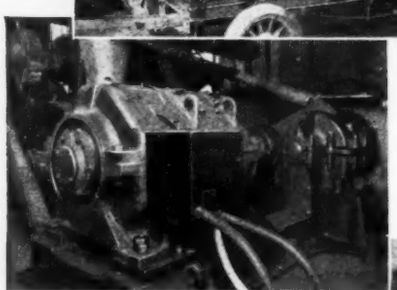


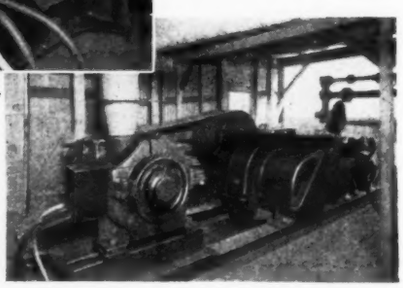
One of two 125-kw. generating units, mounted on a barge, supplying power to a G-E direct-current rotary-rig drive



Two gasoline-engine-driven 75-kw., direct-current, G-E generator sets for rotary drilling, mounted on trailers for ready portability



Enclosed, separately ventilated, direct-current drawworks motor



Mud pump driven by G-E separately ventilated direct-current motor

G-E direct-current drives for rotary drilling rigs offer you the unusual flexibility and wide speed range heretofore thought to be obtainable only with steam.

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Where power can be taken from transmission lines, these and many other advantages may be realized by using a G-E motor to drive the generators.

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GENERAL ELECTRIC

kets. The market can be transferred, to some extent, from one company to another, but how can any company be so egotistical as to believe that it can prosper to the exclusion of others? Yet this appears to be the attitude of a few companies. This may appear to be a criticism of the marketing branch, but it is not meant to be so. The real responsibility lies in the refinery laboratory and management, which instigate the activities of the marketing departments. There is no reason for the manufacture of products that are possibly superior from a technical standpoint but show none of this superiority when used in the automotive engine. These slight improvements often increase the manufacturing costs far more than the usefulness or price of the product is increased. Such marketing activities are short-sighted and yet many of the improvements of the last few years have been of this nature. The industry has boosted itself into much higher manufacturing costs, all for the paltry extra profits which one or a few companies can make during a period of a few months or, at the most, a year.

Coöperation between the companies themselves is the only logical manner of meeting this situation. Continued thoughtless competition will be a detriment to all. Legal restrictions or codes cannot take the place of wholesome coöperation between refiners.

Solvent Extraction

No single development has attracted more widespread attention during the year than solvent extraction. This operation differs from treating in that no chemical reactions are involved. The action is a purely physical one in which part of the oil is dissolved in the solvent and the rest is left behind as an insoluble portion. A race has developed among refiners in an attempt to improve the viscosity-index of their oils, decrease the carbon residue and reduce the pour-point. The extraction methods are the only methods for the improvement of the viscosity-index that have proven to be commercially practical. These methods have been studied and appreciated for several years but funds and the proper stimuli have not been available until the last year. All refiners see the opportunity to develop oils that compare with Pennsylvania oils and the Pennsylvanian refiners see an opportunity to produce oils that compare favorably with the oils produced by hydrogenation. By the solvent extraction of paraffin-base oils the already good viscosity-index of these oils can be further improved.

At the present time seven of the major companies are operating solvent extraction plants. The total capacity of these plants is about 7500 bbl. per day, although 3500 bbl. of this capacity is being processed in a French refinery. The number of plants that are under construction is even more imposing. Seven plants with a finished daily capacity of 9500 bbl. are under construction. In addition to these, eight other refining companies are seriously considering the installation of plants. The construction to date and the contemplated construction will probably exceed an expenditure of five million dollars.

Not all refiners are satisfied that solvent extraction oils are sufficiently superior to justify the construction of plants. Only a few road tests and engine block tests have been conducted to determine the superiority of these oils. Whether or not these tests have been comprehensive enough to prove the reputed superiority of high viscosity-index oils yet remains to be seen. Many refiners feel that the viscosity-index may be of importance in cold climates during that short period when the engine is being started but in such climates crankcase dilution is also active and to some extent nullifies the advantages of a high-index oil. Thus by advertising and by competition the industry has been forcing itself into the adoption of expensive treating processes that may not be justified. Only time can show whether these solvent methods justify the added expense.

The solvents that have claimed attention are: (1) Phenol, (2) Dichlorethyl ether (Chlorex), (3) Sulfur Dioxide-benzene (Edeleanu), (4) Nitrobenzene, (5) Furfural, (6) Propane and a blend of cold tar acids and bases (Duo-sol), and (7) Propane. At present the processes seem to be on an even footing but the interest is so keen that the next year will doubtless prove the superiority of some processes and cause the development of others to be abandoned. There has been a constant hope that a combination process of treating and dewaxing will be developed. The propane process, at present, seems to lend itself most easily to combined extraction and dewaxing. The asphaltic constituents of the dark petroleum residues are nearly insoluble in cold propane and hence these asphaltic materials are separated to some extent during dewaxing by the propane dewaxing process.

Solvent Dewaxing

Solvent dewaxing has also claimed attention but in difference to the development of extraction processes the dewaxing methods are based on sound economic principles. The influence of competition and advertising are not directly involved so that the processes have been free to grow on their merits; that is, if they are more economical than the processes that are now used. The dewaxing of wax distillate in frame-type presses and the centrifuging of bright-stock solution have long been recognized as expensive processes. The development of solvent dewaxing gives hope that cheaper methods will soon be available. The most widely known new processes are (1) Filtration and Refrigeration in propane solution, (2) Filtration in benzol-acetone solution, (3) Filtration by the use of filter-aid, and (4) Centrifuging in Trichlorethylene solution. Doubtless one of these processes, or a new process similar to these will soon be adopted as general practice. No superiority is claimed for these processes except the economy of operation. Expenses may be less because of a more rapid rate of filtration, because both the wax distillate and the cylinder stock can be processed in a single system or because self-refrigeration is possible. The development has been impeded by the lack of adequate recovery systems for the solvents. No solvent dewaxing process can be truly successful unless the loss of solvent is very small. An alternate is to develop a cheap solvent; but little hope can be held for developing a solvent that is cheaper than propane. At present, the propane process, because of the advantages of self-refrigeration and the easy recovery of the solvent in the regular absorption system of the refinery, appears to be most successful.

Plant Modernization

The modernization of obsolete equipment by additions and new installations has been progressing rapidly. A precision in refinery processing systems is appearing that comes only after technical knowledge is generally utilized. Development has been so rapid during the last ten years that at no time in this period could a process be said to be perfected. Finally, and greatly during the last year, certain of these processes have proven beyond doubt to be sound methods of processing and an era of detailed development has been made possible. Except for minor changes these processes, mainly those of distillation, will remain for years as standard processing methods. Technical men have been aware of the fundamental nature of these processes but not until recently have they been generally accepted by all refiners.

This confidence of the refiner has resulted in a great modernization program in which older equipment has been replaced by pipestill and fractionating tower systems in almost all phases of distillation processing. Modernization has been most active in the Pennsylvanian district. No less than nine new distillation units have been installed in this small district during the last year. In addition to these, several new cracking and reforming plants were installed. Pennsylvanian refiners have had to meet the demand for anti-knock gasoline by a further development of their cracking facilities. The develop-

ment in this district has not been limited to distillation equipment alone. Effective laboratory control methods have been developed to an extent that is unknown in most other sections of the country. In adopting thorough laboratory control methods the Pennsylvanian district is showing the same wisdom that has so often kept it in advance of other districts.

In other parts of the country, and particularly in the Mid-Continent area, the construction of asphalt vacuum plants has attracted much attention. The fact that marketable asphalt and road oil can be manufactured from cracking still residues has been demonstrated. A wide variety of stocks which were heretofore considered as unsuitable for asphalt manufacture, can be processed by vacuum distillation.

In cracking systems the tendency has been to build combination units. In these units the operations of cracking, topping of crude oil, reforming of low octane number naphthas, viscosity breaking and in some cases the stabilization of the cracked naphtha may be conducted as one combined operation. In a cracking plant there is always a large quantity of heat that may be utilized if only the proper methods of heat recovery can be applied. Not only a large amount of heat is available, but it is at a high temperature as well. These combination processes have been developed in an attempt to utilize this large source of heat. The general tendency in the operation of cracking plants has been the use of higher temperatures and lower pressures, although those processes that still employ reaction chambers have in most cases gone to higher pressures. The use of higher temperatures and lower pressures has been the result of the increasing demand for high octane number fuels. For the same reasons, vapor-phase processes of cracking have gained on the other types. The patent situation has been somewhat clarified during the year. The Universal Oil Products Company sued the Root Refining Company for infringement of two of its patents. The patents were held to be valid for the case in hand but the extent of the damages has not been determined. The Root Company has been using a cracking process that is similar to the Winkler and Koch tube type of cracking plant.

In distillation processes there has been a marked tendency to give attention to details of construction, design and operation. It has become common to produce products that have a "gap" between the boiling-ranges of one product and the product next adjacent. Fractionation has been so generally improved that "gapping" is possible even when producing solvents that have a narrow boiling-range. Another tendency in distillation plant design is the use of a single system for the distillation of two or more stocks. Plants are operated for the processing of either (1) crude oil or bright-stock solution, (2) pressed distillate or bright-stock solution, and (3) crude oil, solution or pressed distillate.

Laboratory Methods

The two improvements of note in the laboratory field are the adoption of a standard test method for determining the detonation properties of motor fuels and constant improvements in the methods for determining gum. Both of these tests have been a source of confusion for many years. The Motor Method of determining octane numbers using the CFR test engine has been adopted by the industry as well as by Committee D-2 of the American Society for Testing Materials. This method, at the present time, is the best that has been developed for correlating laboratory knock tests and road performance data. The method is similar to the Research Method, which has been previously used, except that the inlet temperature is 300 deg. fahr., and the speed is 900 rev. per minute. Those who have been familiar with the confused state of anki-knock testing during the past are grateful for the adoption of a reliable standard method.

The improvements that have been made in methods for determining gum have not been wholly satisfactory. However, the industry has reason to be hopeful because of the general interest in the oxygen-bomb tests that are being promoted by the Naval Experimental Station at Annapolis, the Ethyl Gasoline Corporation, many of the larger companies and several instrument manufacturers. Most laboratory men feel that the oxygen-bomb methods are far superior to any that have been heretofore proposed. In these tests the sample is heated (usually at 212 deg. fahr.) for a period of time in an atmosphere of oxygen. The pressure is about 100 lb. at the beginning of the test and the rate of increase or change in pressure is related to the gum-forming tendency. However, the gum is usually subsequently determined by the accelerated porcelain dish method. At the present time these methods promise to displace the dish methods, the 90-day storage method and other long-time tests.

The awakening of an interest, on the part of refiners, in fundamental laboratory evaluation and control methods, has been gratifying. The larger refiners have used such methods for years but the smaller ones have usually been content to gather general information from magazine articles and by rumor. No one can state exactly when changes of this nature take place, or when the change becomes general practice, but the last year has brought an interest that appears to be genuine. The Pennsylvanian district has been most active in adopting advanced laboratory methods.

Alloy Tubes and Fittings

Interest in alloy tubes and fittings has been greater than usual during the year. This has been due primarily to the development of satisfactory alloys that are inexpensive. The use of 4-6 per cent chromium steel tubes for pipestill heaters and for high-pressure valves and fittings, and the use of high chrome-nickel steel castings for tube supports is fast becoming universal practice. Chrome-nickel alloys are much more resistant to corrosion than carbon steel and they retain their strength at elevated temperatures. During the year the importance of molybdenum as an alloy element has become generally known. Very small amounts of this metal (0.5 to 1 per cent) greatly improves the strength of most alloy steels at high temperatures. Tungsten has much the same effect but it is about half as powerful and it is much more expensive. Simple carbon steels containing only 0.5 to 1 per cent of molybdenum have been reported that have a remarkable strength at high temperatures. These are the first pearlitic steels to receive widespread attention because of their strength at elevated temperatures. In the past, the austenitic steels that contain high percentages of chromium and nickel (and other special elements) have been promoted. The rate of creep of the low molybdenum steels has been reported as 12,000 lb. per sq. in. at 1000 deg. fahr. in 10,000 hr. (42 days) with an elongation of only one per cent (0.5 Mo. steels) and even a higher strength is reported for the one per cent molybdenum carbon steel. Such steels have a tremendous advantage over other steels because of their cheapness. Whereas the high chrome-nickel steels have sold for as much as 50 cents per pound, these alloys can be obtained for about 13 cents. Thus they fill the urgent need for superior materials at a price that permits extensive use. They are not greatly resistant to corrosion.

The American Society of Mechanical Engineers, the American Standards Association and the American Petroleum Institute have been active in promoting the study of the retiring strength of petroleum equipment. This interest has largely centered about the retiring thickness for pipe, tubes, valves and fittings. The investigation is timely, for although most engineers are able to select the strength or thickness of new equipment, few of them can wisely say when an existing equipment begins to be unsafe. If an error is made, fires or explosions, which may endanger life and property, may occur. Attention to such problems is now particularly important because the industry is beginning to adopt standard equipment that will be expected to perform for many years.

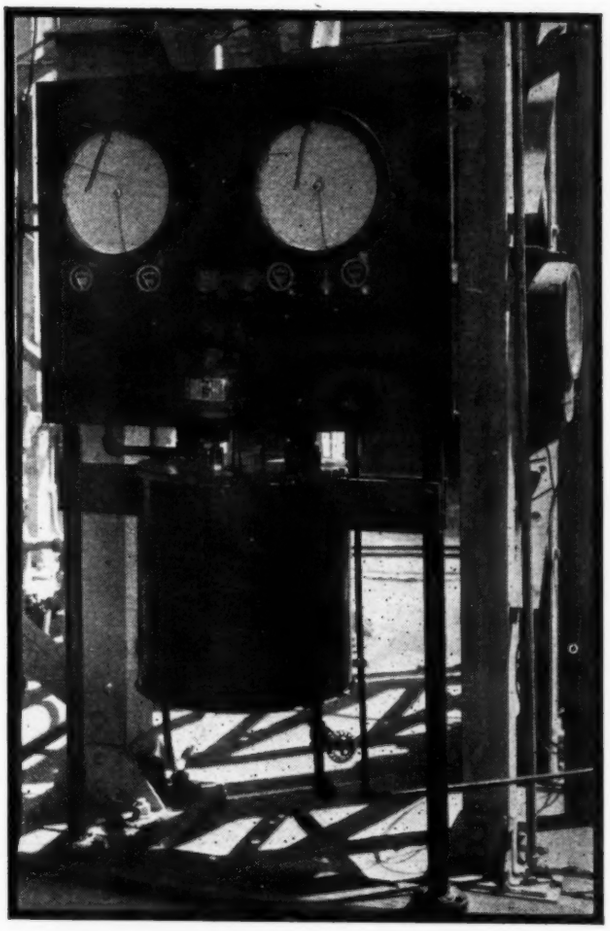
Twelve Months of Progress in The Natural Gasoline Industry

THE rapid recovery of refined oil prices during the last half of 1933, from the lowest level reached in the history of the industry, was not sufficient to prevent that year from being the "worst ever." Although natural gasoline is not a direct product of crude oil, it did not escape this demoralized market. In June, the 26-70 grade of natural gasoline sold for as low as one cent a gal. in Oklahoma.

The past 12 months will be remembered by the low volume of purchases of natural gasoline by refiners as compared with other recent years. At the start of this period it was thought that the adoption of the use of tetraethyl lead in the second grade of motor fuel would have the opposite effect. It was hoped that when refiners adopted this method to increase the anti-knock value of their gasoline in lieu of cutting endpoint or reforming, it would create a greater need for natural gasoline. This measure does appear to have retarded the building of further reforming units to produce cracked gasoline. The rise in yield of the units operated, however, together with the light gasoline recovered from the cracked vapors, permitted the refiner to gain volatility by the use of a smaller quantity of natural gasoline.

Another factor that hampered the extended use of natural gasoline by the refiner was the cost of transporting the product from the points of manufacture to refining centers. This is apparent from the areas of the Mid-Continent and California where the bulk of the natural product is made. In these sections a much larger proportion of motor fuel is natural gasoline than is the case on the East Coast.

The refining of East Texas crude also reduced the volume of natural gasoline consumed at Gulf Coast points. This resulted from the fact that this oil has a relatively high percentage of light fractions, such that the gasoline produced from it has the necessary volatility without the addition of natural gasoline. Crude oil was produced so cheaply in this section that refinery gasoline sold below the manufacturing cost of natural gasoline.



Vapor pressure recorder installed on a natural gasoline stabilizing unit

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The production of gasoline from gas in the East Texas field increased during the period under consideration, as did that in the Panhandle area. The latter resulted from permission given by the Texas Railroad Commission to process gas in this territory without providing a use for the residue gas. Gasoline from the Panhandle is of relatively low volatility, and so was particularly suited for disposal in direct competition with refinery motor fuel. The diversion of natural gasoline away from the refiner to the marketer or jobber has resulted in further depressing the motor fuel market, and hence the natural gasoline market as well.

The actual decrease in the production of natural gasoline can be accounted for as resulting from curtailing the production of crude oil in the older prorated fields. As is generally customary, the stocks of natural gasoline declined during the early winter months with a corresponding increase in market price. On the whole, natural gasoline seems to be an excellent example of the law of supply and demand.

A New Price Schedule

A year ago May a new policy was inaugurated on the Pacific Coast for purchasing natural gasoline in the field. This policy, which is still in effect, consists of a graduated price schedule predicated upon the quality of gasoline produced and the relative distance of fields from the centers of consumption. Vapor pressure is the dominating factor in this schedule, the prices being graduated downward from 5.3 cents per gal. for natural gasoline of 15.0 to 15.9 lb. pressure to 3.3 cents per gal. for natural gasoline having a vapor pressure between 52.0 and 53.9 lb.

Minor variations exist between fields in the same section of

the State due to fundamental differences in the component fractions of the gasoline. Experience with high-octane motor fuels indicates that the proper use of natural gasoline running between 16- and 20-lb. vapor pressure brings the best results. It is obvious that the graduated price scale tends to improve the quality of the natural gasoline produced. Under the present economic conditions, changes in operating technique have been almost entirely responsible for products falling into the higher price-brackets.

New Plants

The last two years emphasized the almost complete lack of building or substantial plant improvements in the natural gasoline industry. Market conditions for the product have simply not been conducive to such enterprises. With the upturn in prices during the early winter, the new year commenced with a relatively large amount of new activity, and, although the market has not retained the October level, it has been high enough to encourage the building of a few plants in certain fields.

Although East Texas was not looked upon originally as a large source of natural gasoline, the gas has increased in richness with the decline of the field presumably to warrant the erection of a considerable number of plants. Other operators have added to their plants during the past six months and still other plants are proposed. This field is characterized by the large number of wells required to supply gas to any single plant by reason of the small gas-output per well.

The remainder of the building activity was confined to the Texas Panhandle, where the older plants also added to their gas supply by laying additional trunk-lines. Of the 25 plants installed during the year, California contributed but three, having a total combined capacity of but 44,000 gal. per day.

Operation and Maintenance

Operating difficulties have increased immensely over the past year by virtue of proration orders. Probably the most difficult to solve were those of the Oklahoma City field where the Governor ordered sharp reductions in the output of the field. In these early stages of enforcing proration, a plant had to be prepared to take gas whenever the producer found it advisable to produce his allowable for the month. As a result, a part of the time there was excess gas coming to the plant and at other periods there was not sufficient gas to hold normal operating temperatures and pressures upon the system. Problems in other fields have been similar but perhaps not so drastic. As a result of this enforced type of operation, the extraction efficiency of the entire industry has been lowered.

Two years have passed since material repairs have been made to the plants of the industry. Plants, aside from becoming more obsolete, are in a far worse state of maintenance than ever before. In fact, many are becoming dangerous to operate. Because of the strained economic condition there has not been the usual free spending of money for equipment and repairs. As a result, plants have not been in proper shape to cope to the best advantage with the changing field conditions. The effect of this "holiday" remains to be seen, but it is expected that as soon as natural gasoline prices move up nearer to a normal level, the manufacturer will show a willingness to correct these deplorable conditions.

Safety

During the past year in the natural gasoline industry the number of disabling injuries per million of man hours worked has decreased about 20 per cent over the previous 12 months. This is in direct contrast to an increase of 5.9 per cent for the entire petroleum industry over the same length of time.

On the other hand, the severity rate, or the number of days lost per 1000 man hours worked, increased over 62 per cent in the natural gasoline division. The severity rate of 5.37 was the highest on record for any division of the petroleum industry, in fact, the latter established a figure of 1.90 for this same period. It is interesting to note that this is an all-time low record. The high increased severity rate in the gasoline division can undoubtedly be traced to the additions throughout the year of inexperienced workers under the NRA Code, and to the condition of the natural gasoline plants.

Plant Development and Practices

As might be expected from the relatively small amount of new construction during the past year, little advance can be reported in the way of new gasoline plant design and practice. Many of the new plants were justified for the reason that they were a means of returning dry gas to the crude oil bearing sands for repressuring. The gasoline in these cases was more or less a secondary matter.

In those sections where an abundance of high-pressure gas existed there was a more pronounced trend toward the use of gas for driving all plant pumps, centrifugal and reciprocal alike. Steam in these installations was generated only for the purpose of process work. A further use of excess high-pressure gas was made in one instance for recirculating cooling tower water. In this case the gas was utilized for jetting the water from the basin on top of the tower, the maximum circulating rate for the water being 2000 g.p.m.

Those few plants not already equipped with stabilizers added this equipment during the year. Such units are now an absolute necessity in order to meet the fluctuating market conditions. In one plant, the range of product varied from the regular 26-70 grade to a well stabilized 14-lb. vapor pressure product during certain seasons of the year.

Several stabilizer units were installed expressly to manufacture liquid butanes and propane, and in other plants, older stabilizer units were rebuilt or operated so as to produce these products. Many companies operating refineries, as well as gasoline plants, now transport their natural product direct to the refinery. This gasoline may be either the raw product or one that has been subjected to partial field stabilization. At the refinery the entire natural supply from adjoining fields is stabilized in one large central rectifying plant. Such plants are equipped to produce liquefied gas.

Stabilization has thus been responsible almost entirely for the recent interest and activity on the part of the refiner in propane dewaxing. Without cheap propane this process would have remained in the research laboratory, where it has been known for years.

One company equipped its stabilizer unit with a vapor pressure recorder (see illustration), which automatically and continuously measures and records the vapor pressure of the finished gasoline. This device has given improved operation, which in turn has resulted in a more uniform and valuable product.

Hydrogen Sulphide Removal

The presence of hydrogen sulphide in natural gas has continued to present the industry with the problem of purification. Even trivial concentrations of this agent have caused, under certain conditions, severe corrosion of pipe lines. This is particularly true in lines operated at pressures above 100 lb. in the presence of liquid water.

For gas containing these small concentrations, which must be removed, a recent development of the old iron oxide purification method, as used in manufactured gas practice, has

proved successful. This development requires no costly equipment, and the oxide material itself is relatively inexpensive. Finally, and possibly most important of all, it has been shown that by means of the iron oxide mixture the hydrogen sulphide content of the gas can be brought down to the desired concentration of 0.3 grains or less.

The gas is passed through a bed of the oxide, revivification of the oxide material being accomplished in place by the introduction of approximately two per cent air into the unpurified inlet gas. The inlet gas must also be saturated with water vapor at the scrubbing conditions. On the basis of treating three million cu. ft. of gas daily, the cost is reported to be about 0.54 mils per M cu. ft. for this installation.

Gas Dehydration

A number of cases of internal corrosion of natural gas pipe lines were brought to light during the past year. Such corrosion continues to occur in the presence of liquid water, and either oxygen or hydrogen sulphide, or both. In no case has corrosion been reported in the absence of liquid water.

The presence of any one of these agents in a pipe line, however, does not necessarily mean corrosion is taking place. The occurrence of the corrosion depends upon so many factors, such as pressure, concentrations of reacting substances, drainage, and many others not yet thoroughly understood. It is, therefore, exceedingly difficult to predict when and where corrosion will occur. Corrosion may be found in one section of a line, and not in others. Numerous inspections of the line must be made before it can definitely be said that corrosion does not exist.

The liquid present in pipe lines results from condensation. Natural gas as it comes from the gasoline plant is usually warm and saturated with water vapor. Upon entering the pipe line its temperature drops, and as a result, water vapor condenses. It is at these points that internal corrosion is usually encountered. In some places, companies are greatly concerned with this problem as the water actually freezes at certain times of the year. Some of these "freeze-ups" have taken place at temperatures well above the normal freezing point for water. Such "ice" is now believed to be the result of a butane cryohydrate formed at reasonably low temperatures and high pressures. Present opinion is that the elimination of the condensed water vapor from the pipe line will forestall this ice formation. There is little doubt that total removal of both oxygen and hydrogen sulphide would practically stop internal corrosion, but commercially such removal is impractical. Dehumidification of natural gas, therefore, appears to be the practical method of preventing this type of corrosion.

One such dehydration plant was installed this year that employs ammonia refrigeration for lowering the gas temperature. In this system the main line gas is cooled in a gas-to-gas exchanger followed by a final cooling in an ammonia chiller. Such a system is quite adaptable to companies operating compressor stations having idle equipment.

At present a second dehydration plant is under construction. This unit will operate upon the absorption principle, employing the use of Silica Gel.

The continuation from year to year of this internal corrosion difficulty has resulted in a new policy on the part of several companies taking gas for industrial sale. New gas-purchase contracts will contain clauses covering the allowable quantities of hydrogen sulphide, oxygen and free-water that will be permitted in the delivered gas. Such procedure will throw the burden of cleaning the gas upon the seller, or the gasoline manufacturer in most cases.

By-Products

The problem of finding and developing new products and outlets for these products is one that is neither new nor unique in the natural gasoline industry. That such effort is justified may be seen from the present state of one of the industry's two commercial by-products. This situation is that there is now in storage in the United States a sufficient supply of carbon black to fulfill the demands of the entire world for a period of approximately two years. To this must be contrasted the condition of the refining industry wherein a new resin, competitive with resins like Bakelite, is finding a ready market. This material is produced from refinery cracking plant gas. Similarly, this type of gas is also furnishing practically all the ethylene glycol used for anti-freeze mixtures.

Faced with this economic problem of utilizing possible by-products, the gasoline industry's laboratories are attacking the various problems more intensively than ever before. This work should, and will, eventually link the natural gasoline industry to the chemical industry because of the latter's economic need for sources of more or less expensive hydrocarbons.

Special researches have been carried on in the liquefied gas field. Methods of procedure in chlorination have been developed, resulting in maximum yields of the monochlor derivatives of propane and butane. It is intended to use these derivatives in the production of the corresponding alcohols, esters, ethers, and aromatic hydrocarbons.

Much of the research under way in the natural gasoline industry is not commercially practical in the present stage of development. With processing made adequate to produce the laboratory results, however, it would immediately allow a diversification of the markets, and consequently would add to the stability of the industry.

Liquefied Petroleum Gases

The greatest progress made in the development of market outlets has been in connection with liquefied petroleum gases. Because of the success that has been attained this year in this respect, the subject is deemed sufficiently important to warrant separate treatment.

Probably the most interesting development during the last twelve months in the utilization of liquid gas has taken place in California. Here a decided increase in the use of butane-propane mixtures for motor fuel purposes has been noted with a corresponding lapse in the growth of the market for these same gases as a household fuel in rural communities. This trend warranted a belief some six months ago that if this motor-use continued the situation might get out of hand and result in a sacrifice of considerable gasoline sales volume. As a result, the practice of offering 5-year contracts at 3.5 cents per gal. was discontinued and today a flat price of six cents per gal. exists. This latter price must of course be increased by a 3-cent State tax when the liquid gas is used for vehicle propulsion.

For motor car service considerably higher efficiency is obtained with butane-propane gases than with gasoline. The answer to this would seem to be that the fuel can be better carbureted in a vapor form than as a liquid, and that it is also slower burning. Tests with heavy trucks have developed that where they formerly used 15 gal. of gasoline per eight hours on regular runs, they are now operating ten hours on the same amount of butane. At present the liquefied gas fuel used for automotive purposes in California is edging up towards one-quarter of a million gal. per month. By far and large the most of this gallonage is consumed by truck freight

lines, motor busses and tractors. Only a very few passenger automobiles operate on liquid gas.

It is impossible to predict the future of this business. It would seem, however, that as long as gasoline is available at a reasonable price it should remain the accepted standard automotive fuel. For the present, at least, liquefied gas will make little headway as a fuel for pleasure cars due to the inconvenience of obtaining the gas. In services where this feature is not so vital, liquefied gases are becoming a serious factor.

Much interest has centered about the use of butane-propane as a locomotive fuel on the Pacific Coast during the last twelve months. The fuel was first used experimentally on rail motor cars with results that convinced railroad officials of its many advantages in this class of service. On the basis of these results a gas-electric car was converted to butane and placed on a regular 200-mile run. This car formerly consumed 1½ gal. of distillate and gasoline fuels combined per mile, and the lubricating oil was renewed every 800 miles, whereas on butane, the fuel consumption is one gal. per mile and the oil change is made only after 15,000 miles of operation. This performance is a fuel efficiency of about 0.42 lb. of butane per hp-hr. as compared with 0.55 for the distillate blend.

Liquefied gas fuel is now regularly used on short 3-car trains operating on regular schedules between definite terminals. This fuel has been found to cost two to three cents a mile less than fuel oil. Railroad officials also point out that the gas as a fuel has no odor, is smokeless, and leaves practically no residue.

With the recent advent of the high-speed, stream-lined trains and rail cars, there is a possibility of utilizing even more efficiently the inherent advantages of these gases as fuel for power-generating units. Propane is of particular interest to the operators of such equipment because it has an octane rating of 125 compared with 93 for butane. This high octane rating provides increased hp. output per lb. of power plant, as well as low specific fuel consumption. Still other advantages of propane are that in vaporizing from the liquid state the greater degree of refrigeration available is attractive from the standpoint of air-conditioning the rail equipment. It is also a convenient and economic fuel for heating the passenger sections in cold weather and as a fuel for buffet cars. Liquefied gas has of course been used for some time on air-conditioned diners because of the resulting lower heat load on this type of equipment.

The decrease in gas plants during the past year is good evidence that the construction and operation of central butane plants in the smaller communities has proven more expensive than the traffic will bear. This is due to the depression years having negatived the former expectations of a profitable business. It is expected that this phase of liquefied gas development will pick up as general business conditions improve.

Liquefied gas, particularly butane, has a great deal to recommend it so far as general agricultural purposes are concerned. If its usage were confined to the farm and its tractors and pumping engines only, regulations for its use would be more simple. The extended use in trucks and busses, however, compels the regulations to be more involved. Hazards of its use can be reduced to a minimum only by proper design of equipment, correct installations, reasonable precautions and by proper education of those who may utilize it. The State of California has recently developed a code for prescribing the essential requirements governing the design, construction and operating conditions necessary to secure safety of personnel in connecting with equipment for the storage, handling, and utilization of liquefied petroleum gases.

Construction camps on large municipal and government projects on the West Coast are using the gas for heating, lighting and cooking. Eight-ton locomotives used on these works also burn this liquefied gas, but these are not as yet used in tunnel work.

Another new market has been opened up for butane gas. This is the heating of orchards to prevent damage by frost. Contracts are in progress for installing more of these systems in many citrus groves in Southern California. Another company has developed a burner and auxiliaries which the poultryman is using to distinct advantage in ridding the premises of destructive bacteria.

Still another company, which operates a central plant for service of butane-propane, has instigated a new development. Equipment in this plant is maintained for charging cylinders and the company serves bottled gas throughout its territory. A cold storage plant has been erected at this gas plant that utilizes the latent heat of evaporation of the liquid butane-propane distributed into local gas mains. The cold storage business offers liquefied petroleum gas distribution companies a way by which the hills and valleys of seasonal business can be leveled.

Due to these various efforts to increase the sale of liquefied gases, there is now a daily demand in California of about 20,000 gallons. This is an increase of 3000 gal. per day over the consumption of last year. The distribution of liquefied gases in the United States for 1933 showed an increase of approximately 4,800,000 gal. or 14.1 per cent, compared with the total marketed in 1932. This gain, although not so great as recorded in previous years, indicates a steady growing demand for these products. The greater portion of this year's increase was in industrial service.

There are several other recent developmnts in the use of these fuels, one of which is its us as boiler fuel on isolated drilling wells. At the present time liquefied petroleum gases are being used extensively by several motor car manufacturers for block testing or "running in" of all their engines. The fuel is also used for large stationary engines, direct-connected to generators, by many public utility companies and oil companies.

The patented automotive-refrigerating system, developed two years ago, for preserving perishable foods in transit or for air-conditioning of busses and other motor carriers, is now on the market. The equipment in this system consists of a valve arrangement permitting easy conversion of automotive equipment to the use of butane-propane gas as a motor-fuel, and of a refrigeration coil to be installed in the motor vehicle body. In this coil, the expansion of butane-propane furnishes refrigeration sufficient for the preservation of perishable foods.

Certain large refineries, not finding a sufficient market locally for petroleum gases, decided to export it rather than to curtail its manufacture. As the butane has such a high vapor pressure it must be blended with other products having a much lower vapor pressure in order to be safely shipped by tank steamers. In order to procure a proper blending medium of products already being shipped to foreign ports, one company found it necessary to use cargoes of naphtha refined in its South American refinery. A bonded manufacturing warehouse has been established in this country for the purpose of holding these cargoes while the surplus butane is admixed with the naphtha. The resultant blend, having safe volatility and pressure limits, is then reshipped to its destination.

Coördination of Factors Governing Bit Performance in Rotary Drilling

By WALLACE A. SAWDON
Petroleum Engineer,
Los Angeles,
California

CO-ORDINATED control of all the factors that influence the progress of a drilling well will naturally result in the greatest efficiency and safety. Weight control has played a big part in rotary drilling and has demonstrated its necessity. Co-ordinating the performance of other equipment with the weight being carried on the bit, however, offers possibilities of more nearly perfect drilling control. The driller is becoming more and more a scientific operator. He wants every piece of equipment on his rig to give the best performance possible; and it is only by knowing what the equipment is doing that he can determine its efficient operation.

Rotating Speed

During the past year or two, some of the larger oil companies in California have been making a study of the effect of rotating speed on drilling progress. Tachometers have been used to measure speed on rotary wells since 1929, but the recent experiments were made to determine the efficiency of different speeds and to regulate rotating speed during drilling.

It is difficult to state just what should be termed high-speed rotation at the present time. A rotation of 125 r.pm. is considered high speed by most of the companies in California; yet one company at least may already think this is relatively low since it has used speeds as high as 250 r.p.m. on several of its wells.

Of first consideration in the study of speed was its influence on the life of the bit, the amount of hole drilled per hour, the depth drilled per bit and the quality of the hole. These have a direct bearing on the drilling progress, the straightness of the hole and the drilling speed; but the experimental work of some of the companies went further and presented data on the influence of rotating speed on surface equipment and general drilling control.

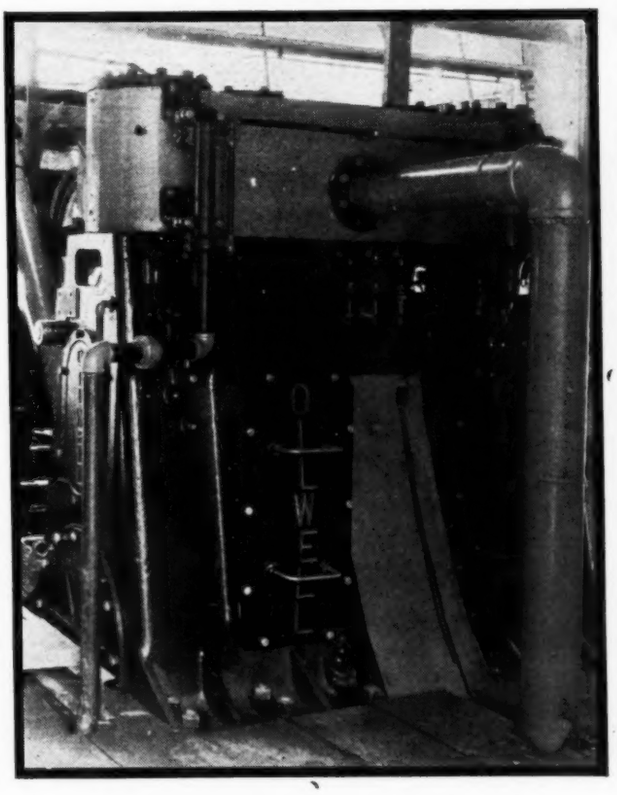
Various kinds and makes of bits were used to show the results obtained by the different speeds. It was discovered, moreover, that the use of a tachometer to measure rotating speed often furnished a most dependable means of trying out the bits.

The first thing to consider in using increased speed of rotation is the greater impact of the blow that is given to the formation by the bit. Theoretically, the force of impact varies directly as the square of the speed. This means that a speed of 100 r.p.m. gives an impact four times as great as the speed of 50 r.p.m., all other conditions being the same. While this ratio is probably not strictly correct for a bit rotating in the bottom of a hole where so many extraneous factors affect its performance, it is evident that the cutting action available at high speed is considerably greater than at low speed.

In hard formation and with some type of bit, this will result in a great increase in drilling speed. A greater rotating speed, however, should then require less weight on the bit for the sake of the equipment and to increase the assurance of a straight hole. Actual tests have borne out this conclusion and most of the companies using greater rotating speed are applying less weight on the bit.

The effect of speed on the bit itself is naturally an important factor; and the speed at which a bit will cut best is, of course, the proper speed to use. With this speed determined as to its effect on the amount of hole drilled per day and per bit and on the life of the bit, it can then be maintained to procure the maximum drilling progress. One company using a speed that never exceeded 70 r.p.m. stepped up the speed of rotation on all its wells to a minimum of 90 r.p.m. with a consistent increase in the rate of cutting.

A vertical steam engine of recent design used in California on wells at tachometer-measured rotary speeds above 200 r.p.m.

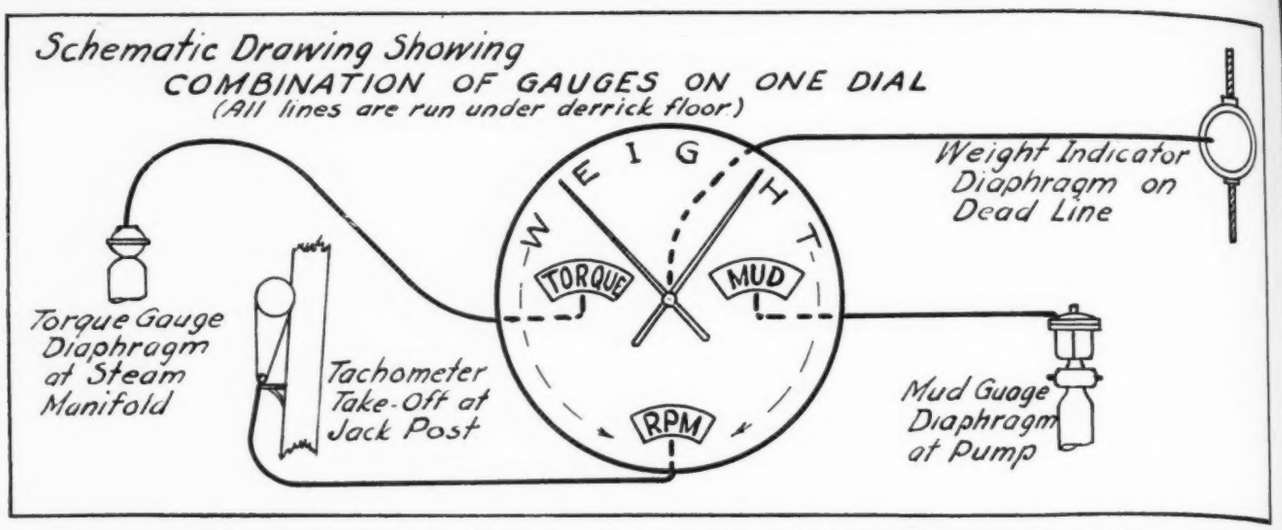


During one series of tests made in Signal Hill with the express purpose of determining the effect of different speeds on various kinds and makes of bits, it was found that most of the bits cut better as the speed was increased. With one make of rock bit and with the weight held constant, three ft. of hole was made at 80 r.p.m., 4½ ft. at 100 r.p.m., and from six to seven ft. at 150 r.p.m.

All types of bits will not, however, drill best at higher speeds. On another series of tests made by another company, a drag bit, for instance, was found to perform best at slow speed. What is desirable is to determine the best speed when combined with the best weight to give the best performance—and then to maintain that speed constantly.

Speed for Coring and Reaming

From experimental work conducted while coring and reaming it has been concluded,



Schematic drawing showing hook-up of the latest aid in co-ordinated rotary drilling control, the Martin-Decker quintuplex instrument

in general, that a speed slower than that maintained while drilling gives better results. In direct contradiction, however, one company has rotated the drill pipe as from 150 to 200 r.p.m. while taking cores. In reaming, however, only one end of the pipe is supported and under most conditions encountered it appears from present data that the rotating speed should be slower than that used for straight drilling. The tachometer has possibilities as a reaming indicator since some of the wall may be missed if the reaming is being controlled by weight alone.

Speed and the Drill Pipe

Whipping of the drill pipe can cause considerable trouble and some engineers assert that many twist-offs are really "wobble-offs" caused by whipping of the drill pipe and failure to keep the bit on bottom. Higher speeds should reduce this whipping; and in this way also help to keep the hole more consistently round and the walls more regular. This contention would recommend considerable increase in rotating speed; but would also necessitate close attention to both the tachometer and weight indicator as a guard against the trouble arising from whipping drill pipe.

Speed and Surface Equipment

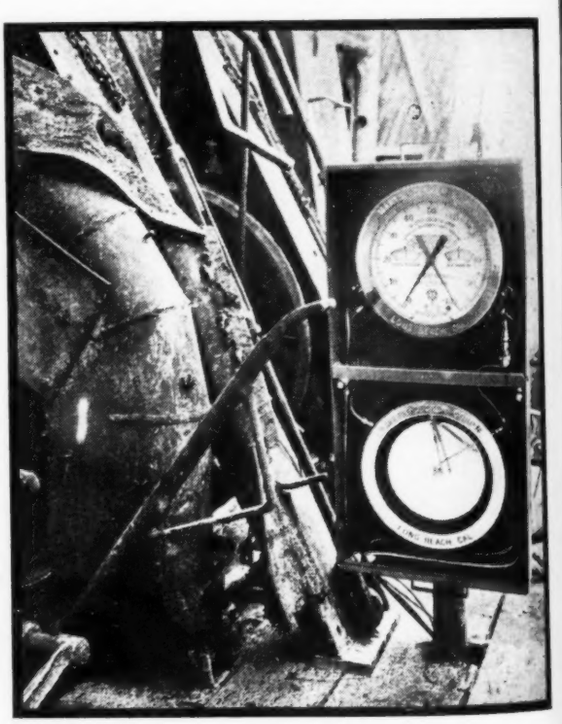
It is asserted by some that speeds of 150 r.p.m. and above are hard on surface equipment. Most of the trouble to date has been with chains that have required more repairs with high speed. There seems, however, to be little difference in the wear of equipment between speeds of 150 r.p.m. and 200 r.p.m. Offsetting the increased wear that may accompany high speeds on certain parts of surface equipment are the effects on the drill pipe. With the greater rigidity and the decreased tendency to bending or wobbling that appear to attend the faster rotation, the wear on the drill pipe is decreased.

Some of the engines of newer type are capable of handling any rotating speed yet used with little or no effect on the engines themselves. It must be remembered that with very high speeds there will be considerable vibration of the derrick floor that may be transmitted to the derrick. The rotary table naturally gets harder use with high speeds and it may be that special foundations under the table could prove advantageous when speeds exceeding 150 r.p.m. are used. Such a table, however, would lose some of its flexibility and might cause greater stress on the chains.

No attempt is here made to state what the maximum limit of rotating speed should be. It is evidently on the increase and probably the influence on surface equipment will present the governing factor. Some companies in California have used speeds as high as 250 r.p.m. One well in the Long Beach field was spudded in at this speed with a special type 27-in. bit. In this operation there was a slight, rapid up-and-down motion of the drill pipe that gave something of a cable tool effect as well as rotary action. The drilling progress was very rapid and the quality of the hole excellent.

Weight on Bit

Conclusions arrived at naturally are different from the experimental work by different companies. They do not all



The Martin-Decker quintuplex instrument installed on a California well.

In full view of the driller are five gauges: Weight indicator, weight vernier, tachometer, torque gauge and mud-pressure gauge. The recorder below gives a permanent record of the weight, steam pressure and mud pressure.

carry the same weight on the bit and they do not all use the same type of bit. Yet there is a tendency to increase speed and all have felt that drilling efficiency can be increased by regulating the rotating speed.

In general, different formations seem to require different rotating speeds. One company, however, uses the same speed for all formations throughout the entire depth of its wells in a certain deep field; but it decreases the weight on the bit in the harder formations. A higher speed than previously used has been found to be more advantageous with the proper cutting tools in most formations; but more diligence with the brake has been required.

High speeds with light weight should also prevent any tendency of the bit to make an irregular cut and eliminate any rifling, for the reamers or reaming edge of the bit will be sure of making contact with the walls of the hole throughout the downward course. If an obstruction is struck, the rotating speed decreases. It will pick up or decrease with every little change of formation. If a constant weight is being carried, therefore, a tachometer will give an indication of the unusual; and such an instrument then becomes a guide in drilling.

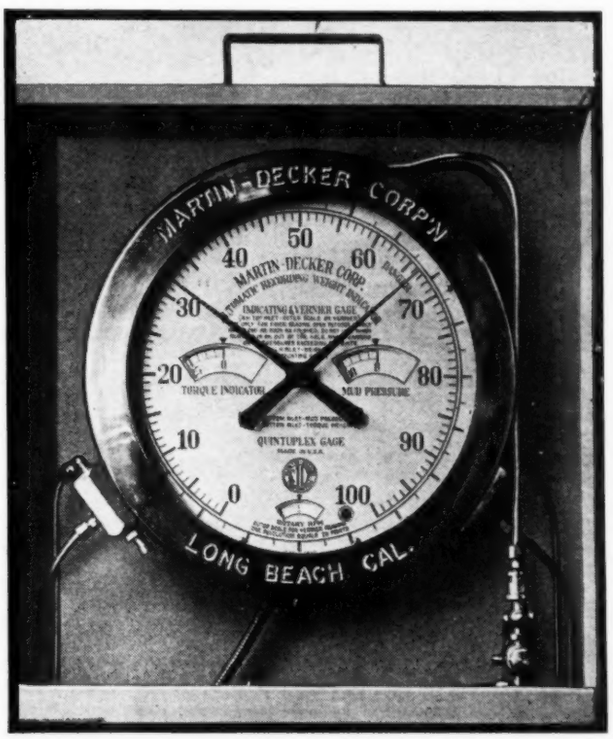
The weight and rotating speed are closely related and the tachometer is certainly valuable in co-ordinating the speed of rotation with the weight carried on the bit to obtain the greatest drilling progress. Moreover, trouble of a certain kind will be picked up by observing the tachometer and weight indicator. The former can be used as a control device if all the other equipment is good and is functioning properly.

In beginning the experimental work on the effect of rotating speed, it was discovered that the rate at which the table was turning was hard to estimate. A driller would think he knew the speed but when a tachometer was installed he would find that his guess was considerably in error—and usually far too high. It was also found difficult to maintain a constant speed without the use of an instrument; yet the maintenance of an established speed or of a minimum was one of the greatest advantages indicated by the experimental work.

Tachometers adaptable to rotary drilling are, however, available. In the accompanying illustration is shown a Martin-Decker combination instrument dial, which includes an indicating tachometer with a weight indicator and its vernier, mud pump gauge and a torque gauge. This type of tachometer has been designed for easy installation and quick calibration so that it can be transferred to different rigs.

The gear ratio adjustor of the instrument is built within its head and is operated with a recorder clock key. To calibrate the tachometer for any rig, the table is rotated at any convenient speed, as for instance 100 r.p.m., and this speed carefully checked with a watch. The ratio adjustor is then turned until the tachometer dial reads 100 r.p.m. The instrument is connected by a flexible armored cable to a small bronze pulley that is mounted on a bracket clamped to the jack post and driven by a flat belt running over the line-shaft or jack shaft.

Close-up of the upper dial of the Martin-Decker quintuplex drilling control instrument



Drill Pipe Torque

While information relative to the power used to turn or twist the drill pipe has been given earlier consideration than that of rotating speed, there seems to be a tendency to utilize the torque to a greater extent and to co-ordinate the control of steam pressure with other factors affecting drilling operations. As here considered, the torque is the power required to turn the pipe and is indicated by the steam pressure in lb. per sq. inch.

For convenience in drilling operations, the torque gauge is divided into "points" similar to the weight indicator. As an example, 25 points may be indicated when rotating off bottom. When the bit is lowered and weight applied, more power is needed to turn the drill pipe and this causes a higher reading, of perhaps 30 points, to be shown on the gauge.

Some recent applications of the torque gauge in California have indicated its value in maintaining better drilling control. When co-ordinated with weight and drilling control it goes a little further toward obtaining a greater efficiency in equipment performance. The knowledge of what the steam pressure is at all times, however, has a definite purpose of its own.

Increased steam pressure must be applied to turn the pipe when extra resistance is required. Such resistance may be due to a "balled-up" bit, a dull bit or a flat cutter. It may be caused by a crooked hole or boulders or junk in the hole. Frequently the increased steam pressure is accompanied by a decrease in speed and such variations are indications to the driller that an abnormal condition exists that should be given attention.

Specific applications of the torque gauge show its use as a drilling guide. In the Kettleman Hills field, a certain type of rock bit used by one company requires 27 to 28 points on the torque gauge to rotate at a speed and weight established by the main office. When the bit gets dull, 30 points are required; and if one or two cutters get locked, about 31 points show on the gauge. This operator states that the tube noise or sense of feel will not give the necessary information and that a torque gauge provides a means of telling the proper time to pull the bit or work a locked cutter loose.

In the Long Beach field, one operator asserts that the torque gauge assisted in keeping a well straight. The well was located in the fault line; it was drilled to 4500 ft. with fishtail bits; no more than one point of weight was carried; and the minimum speed of rotation as controlled with a tachometer was 100 r.p.m. A recording torque gauge was

used and the chart showed no abrupt increases in pressure. When surveyed at 4600 ft., the hole was never beyond the limits of the derrick floor.

The torque gauge has been used in conjunction with the weight indicator in coring operations to prevent crowding and washing away of sample. The assertion by companies that have used it for such purpose is that an unvaried steam pressure insures the cutting of the formation with either hard or soft formation heads when coring either uniform or unconsolidated strata.

The torque gauge included in the combination instrument dial illustrated has a capacity of 350 lb. per sq. inch. It is so constructed that 180 deg. of its dial travel is utilized for showing the first 125 lb. to give closer readings at the lower pressures, in which range most of the drilling is done.

Connection is made by copper tubing to the steam intake manifold. At the manifold is a small diaphragm unit that prevents condensation in cold weather. Steam from the manifold is on one side of a flexible diaphragm and a non-freeze solution fills the system from the diaphragm to the gauge. This not only prevents the condensate from freezing but also keeps oil from the lubricator out of the gauge tube.

Mud Pressure

While mud-pressure regulation has particular advantages unrelated to the performance of the drilling equipment, it provides another advance toward complete drilling control when co-ordinated with weight, rotating speed and torque. Not least, however, is its use in reducing the wear on equipment.

Lower pressures require less steam and fuel; and they are easier on boilers, rotary hose, valves and fittings. In the Gulf Coast and Mid-Continent fields, circulating pressures have been reduced in some operations. Full-hole tool joints have aided materially and the value of such joints has been proved by gauging the pressure carried on the mud fluid. The mud-pressure gauge does not, of course, regulate the pressure but it offers a means of checking up on the pressure and in many cases can be used to determine where lower pressures can be used without cutting down efficiency.

Subsurface conditions in the Oklahoma City field have demonstrated the value of the mud gauge as a preventer of trouble. Here there is excessive cutting, and many fishing jobs have occurred that have been caused by leaks in the drill pipe that, when allowed to continue, have resulted in twist-offs. A drop in pressure indicates such a leak and in one well over twenty "pumped-out" collars and tool joints were caught by utilizing the information furnished by the mud gauge.

A rather unusual case in a California well occurred while coring. The pump pressure started to rise but the core barrel could not be picked up without danger of losing the core. Although rotation was stopped, the pressure continued to rise until it reached 2000 lb. per sq. inch. The pump was stopped until the pressure fell to 1500 lb., and then started up again with the pressure being closely watched. After the pressure again rose to 2000 lb. it gradually decreased to normal when the coring was continued and a good recovery obtained.

The assertions made by the operator were that the electric-driven pump, housed away from the derrick floor, could not be observed by the driller, and that, electric pumps having the faculty of running until either shut off or something gave way, would probably have built up a pressure until something broke had not the mud gauge provided a warning. As it was, the gauge at least saved a round trip and probably a good core.

In general, a mud gauge eliminates any excuse for starting against closed manifold valves. If watched, it should indicate to the driller the condition of the pump itself, even when the pistons or valves go bad. It is especially valuable when electric-driven pumps are used that have been set in a pump house where they cannot be seen from the driller's position.

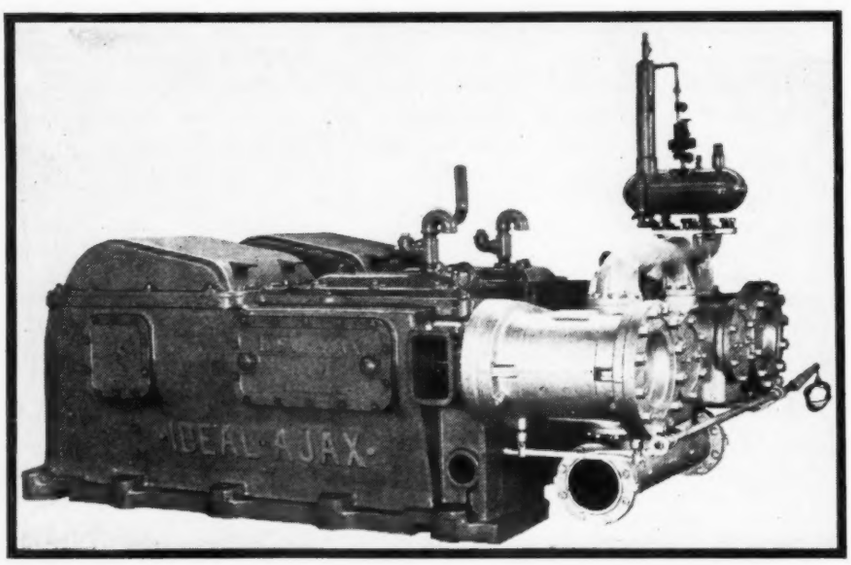
Temperature Compensation

While the control of weight on the bit remains the most vital single factor in drilling here discussed, so much has been written on the subject that no repetition need be given. But the co-ordination of rotating speed, torque and mud pressure with weight control means advancement in drilling practice. As already mentioned, the driller is getting more scientific; and instruments for his aid are becoming more reliable and better adapted for use on the drilling well.

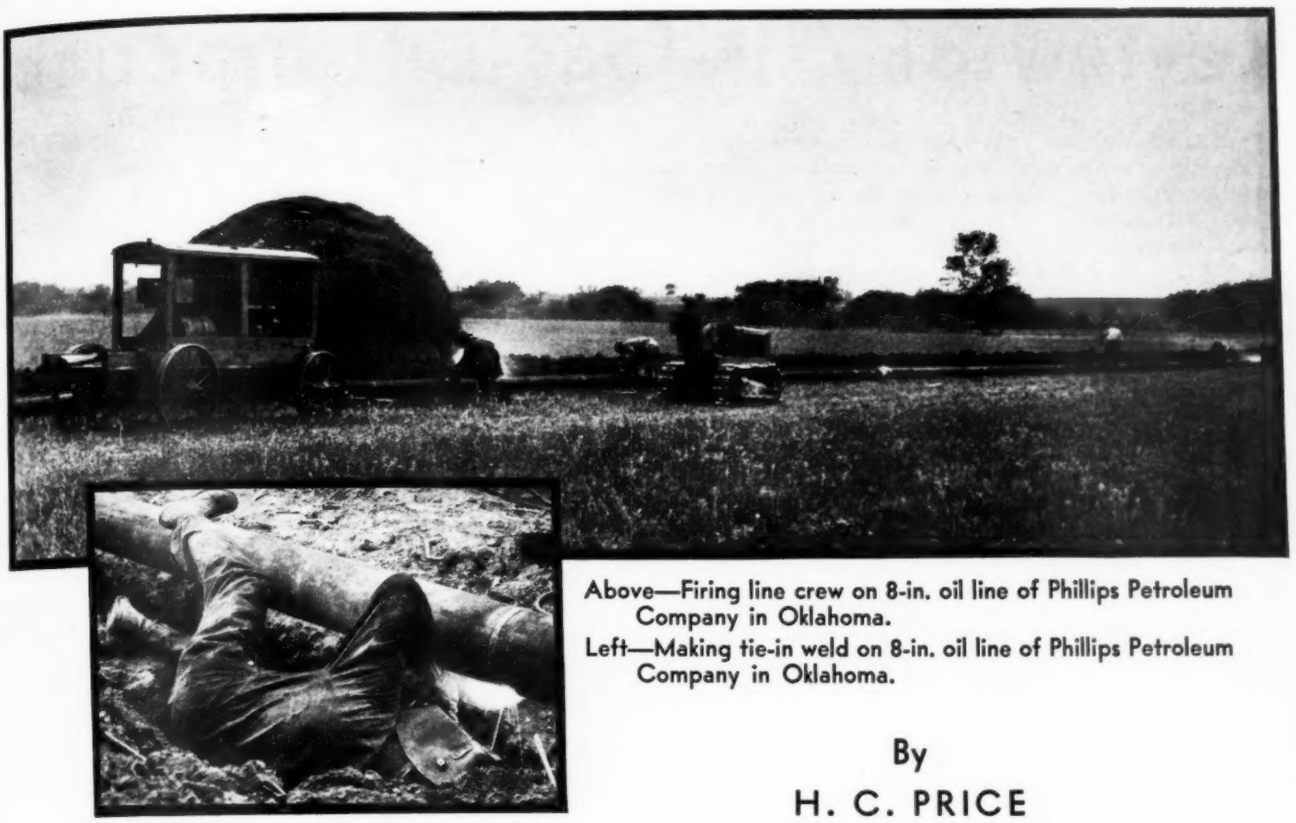
The combination of instruments on one panel facilitates their observation from the driller's position. The installation shown places the other gauges around the weight indicator —which is, probably, as it should be. This particular weight indicator and its vernier, however, has a new feature in its temperature compensation.

Being operated by a closed hydraulic system, the fluid and its container expand and contract with different ratios, which are accentuated by the non-freeze liquids used in the system. To overcome this, bi-metal compensators made of flat, narrow lengths of metal, formed into a U-shape, make the connecting link between the gauge tube and the gauge hand.

With a rise in temperature, the U-shape closes at the top and shortens the distance between the ends. This, by proper design and calibration, pulls the gauge hand back the amount that it would be pushed forward by the expansion of the fluid during a rise in temperature. With a fall in temperature the reverse action occurs.



A horizontal twin steam engine employed for high-speed drilling in the California fields.



Above—Firing line crew on 8-in. oil line of Phillips Petroleum Company in Oklahoma.

Left—Making tie-in weld on 8-in. oil line of Phillips Petroleum Company in Oklahoma.

By

H. C. PRICE

President, H. C. Price, Inc.

Developments in Electric Welding of Pipe Lines

IN considering new developments in electric welding of pipe lines, the Phillips, Sinclair, Great Lakes, Texas and the Stanolind lines are of particular interest. All five were electric-welded without a backing-up ring—the first time this has ever been successfully attempted on field lines of their size. The operation consists of using three beads, the first being, naturally, the most important. On pipe of ¼ in. or greater thickness a space of ⅛ in. is maintained in the lining-up and tacking, and ¼-in. rod is used for the weld. Current must be at least 200 amperes. The second bead is run with 5/32-in. rod and the third with either 5/32-in. or ⅜-in. depending on the diameter of the pipe—5/32-in. being used for 8-in. or under and ⅜-in. for 10-in. or over. The completed weld shows excellent penetration and is flush with the inside of the pipe at least 90 per cent of the time. Another great advantage is that there are absolutely no icicles.

The Phillips, Great Lakes and Stanolind lines were constructed out of new pipe, but the Sinclair and Texas lines used old pipe cut with an automatic torch. No difficulty was found in welding this without the backing-up ring. All the above mentioned lines have been tested under high pressure and no breaks or leaks encountered. The Phillips line was tested to 1200-lb. pressure. Pipe on the Phillips and the Great Lakes lines was of ¼-in. wall thickness, and the Sinclair line was 5/32-in. wall thickness. Shielded arc rod was used on all lines.

On all our other lines, except the ones specifically mentioned, a backing-up ring was used. Since only two beads are necessary when a backing-up ring is used, the welders naturally did not make as many welds per man without it. Our average on the 8-in. line without backing-up ring was 50 welds per man day; on the 12-in. line using old pipe without a backing-up ring we averaged 30 welds per man day. On the 10-in. Western Gas Company line, using a backing-up ring, we averaged 55 welds per man day. Of course there were days when the maximum was considerably higher. We have averaged as high as 60 8-in. welds without ring and 65 10-in. with the ring.

Our company electric-welded 603 miles of pipe line during 1933. This included 230 miles of 8-in. oil line for the Phillips Petroleum Company from Oklahoma City to Burlington, Kansas; 70 miles of 12-in. oil line for the Sinclair-Prairie Pipe Line Company from Teague, Texas, to Singleton, Texas; 20 miles of 6-in. gasoline line for the Great Lakes Pipe Line Company in Oklahoma; 18 miles of 20-in. gas line for the Phillips Petroleum Company in the Texas Panhandle; 50 miles of 18-in. gas line for the Northern Gas & Pipe Line Company in Minnesota and 216 miles of 10-in. gas line for the Western Gas Company from Douglas to Phoenix, Arizona. So far in 1934 we have electric-welded 17 miles of 8-in. for the Texas Company and 30 miles of 12-in. for the Stanolind Pipe Line Company.

Review of Air-Gas-Lift Practice 1933-34

By S. F. SHAW
Consulting Engineer

DURING the year 1933-1934 there has been increased activity in air-gas-lift operations over that of the previous year. The most pronounced increase in this work was in the Oklahoma City field, where pressures in the Simpson zone, and particularly in the Wilcox sand, have declined so greatly that natural flow has rapidly been drawing to a close. The depth of wells in the Oklahoma City field at about 6500 ft. is too great to permit any considerable production to be made by the usual types of pumping equipment, consequently after natural flow ceases potentials must be set up by gas-lift in order that the operator may have any worthwhile allowable. These potentials are established in the Oklahoma City field every six months.

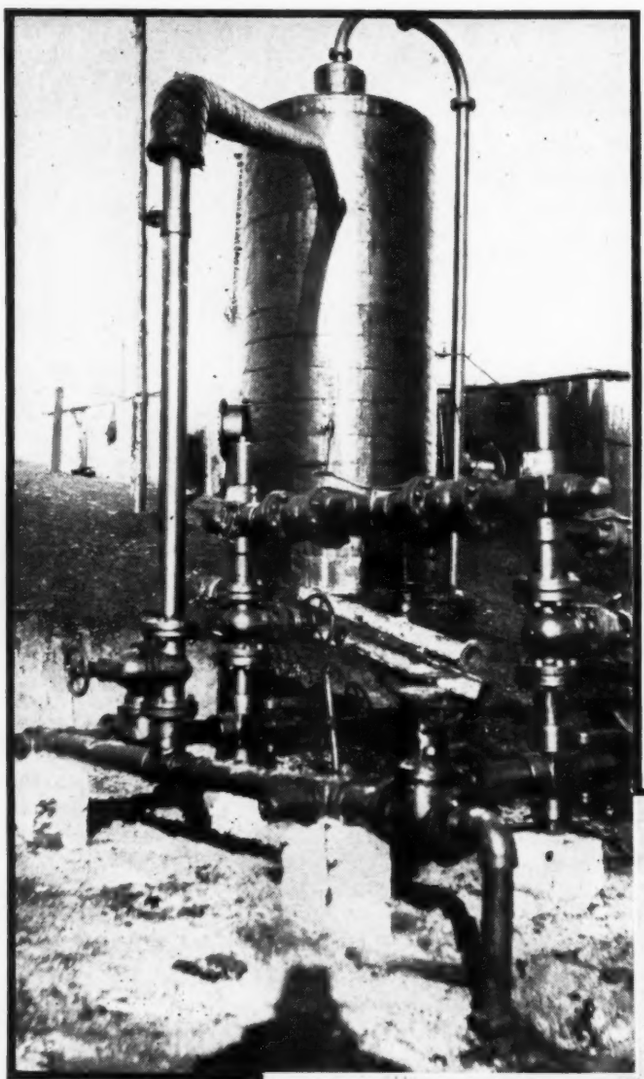
Progress during the past year in air-lift work has also been made in the East Texas field, where allowables are set up as a very small percentage of the well's official potential and where it is compulsory for each well to make its allowable each day. This practice makes necessary the opening and closing in of wells each day. Pressures in the East Texas field have declined from an initial of about 1650 lb. to 1250 lb., and conditions have become such that some of the wells will not start on natural flow when opened, thereby requiring the need for compressors for starting the wells, and in some cases for continuing the flow through the full production period each day.

A modest beginning on gas-lift production has been made in the Conroe field, where two small wells are being produced on intermittent flow with the Hughes plunger lift.

The depth of wells in the Ordovician zone in the Big Lake field, Texas, at 8500 ft. is so great that when natural flow ceased it was necessary to employ the gas-lift for continuing the production.

In the Government Wells field, Texas, proration has necessitated the starting and shutting in of wells each day. In the case of 50 or more wells there have been installed "starting" or "flow" valves, with which the wells are "kicked-off" each day with the aid of natural gas that collects in the annular space between the casing and tubing or is drawn from near-by gas wells. Some wells in this field have been produced to exhaustion by this method.

In the Coyote, Dominguez, Huntington Beach, Long



Above: Hook-up near well in the Ceptura field, Roumania, for flowing with gas-lift.

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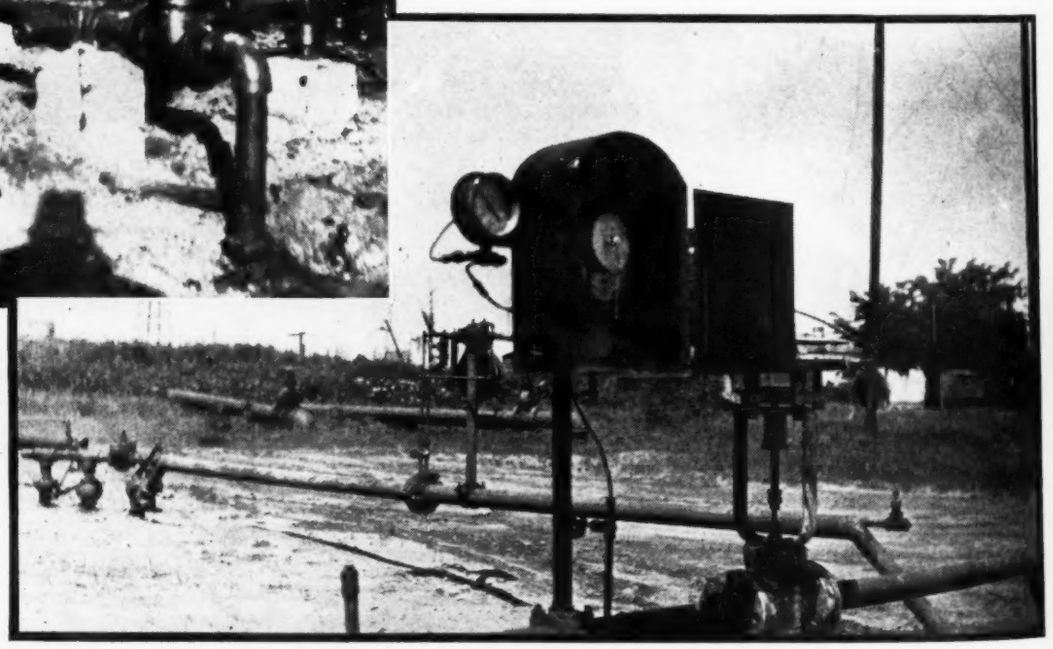
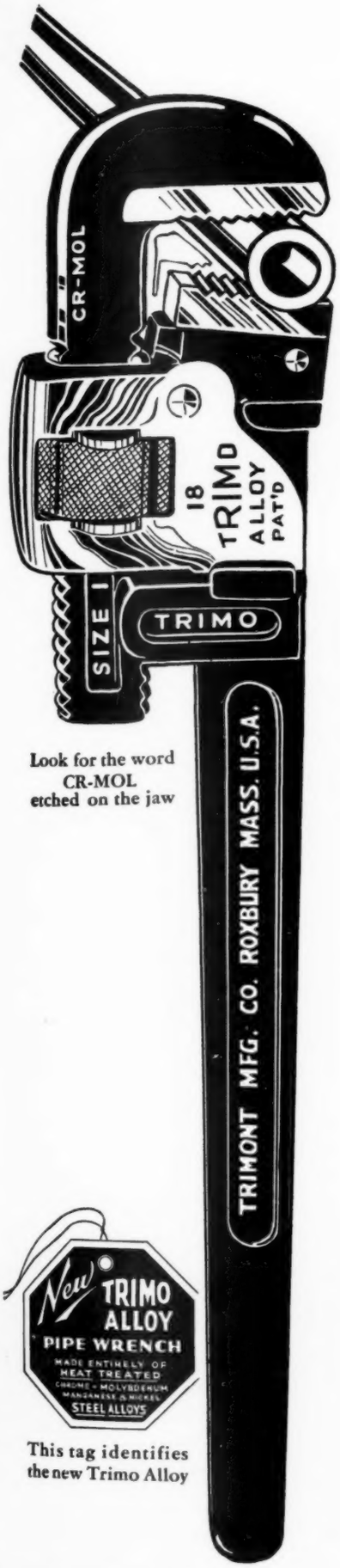
Right: Intermitter employed on a single-well installation, Oklahoma City field.





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Beach, and other fields in California, when wells do not come in on natural flow in a satisfactory manner, compressors have been employed to good advantage, both for starting the wells and for continuing the production of oil.

The gas-lift method is still employed to some extent in the Seminole field, Oklahoma, more particularly where the quantity of water produced with the oil is prohibitive for the usual pumping methods to handle. A few wells in this field have been on gas-lift for about seven years, or ever since they were completed. The production on gas-lift of one major company in the Seminole field is yet about 35 per cent of its total production in that field.

With the very low price received for natural gasoline during the past two years it was found advisable to close down most of the natural gasoline plants in the Seminole field, at which time many of the wells were placed on the beam pump. In the case of 95 per cent of all wells completed in this field, beam-pumping equipment was installed at the time the wells were completed, therefore, the change from gas-lift to beam pump at a time when production had dropped to a low point could be made at a reasonably low expenditure. The more recent production of oil from the Calvin sand in the East Earlsboro pool of the Seminole area has added somewhat to the use of the gas-lift in the past year.

The Cosden plant at Lovell, Okla., has continued on gas-lift throughout the year. The wells of this company are producing 80 to 90 per cent water with the oil.

Decline of production on natural flow in deep wells near the old Moreni field in Rumania has brought about an increase in gas-lift activities in that country.

In the shallow Somerset field, Bexar County, Texas, a lease with eight wells approximately 1700 ft. in depth has continued on periodic air-gas-lift flow through the year. This lease has been producing for eight years and has always been produced by this method.

In Louisiana, at Elm Grove, the Hughes plunger lift has been operating on a small well.

Gas-lift operations have been carried on during the past year in Argentine, Colombia, Peru, Russia and Venezuela.

Methods Employed

Types of gas-lift methods that have been employed during the past year might be classified as follows:

Continuous flow.
Periodic flow.
Intermittent flow.

Continuous gas-lift flow is usually employed where large production is desired. This method has been employed during the year at Seminole, Oklahoma City, Lovell and Rumania, usually in deep wells, also in many cases where it is necessary to lift large quantities of water in order to obtain an economic recovery of oil.

Periodic flow is employed where wells are allotted only a small production per day and are started each day and produced for a short time and then closed in. It is also employed where the oil drains into the well very slowly and builds up a fairly high static head, and is "blown" out periodically. This method has been employed in the East Texas, Government Wells and Somerset fields, in Texas. A few wells in Oil City, Pennsylvania, are said to have produced in this manner for the past 25 years.

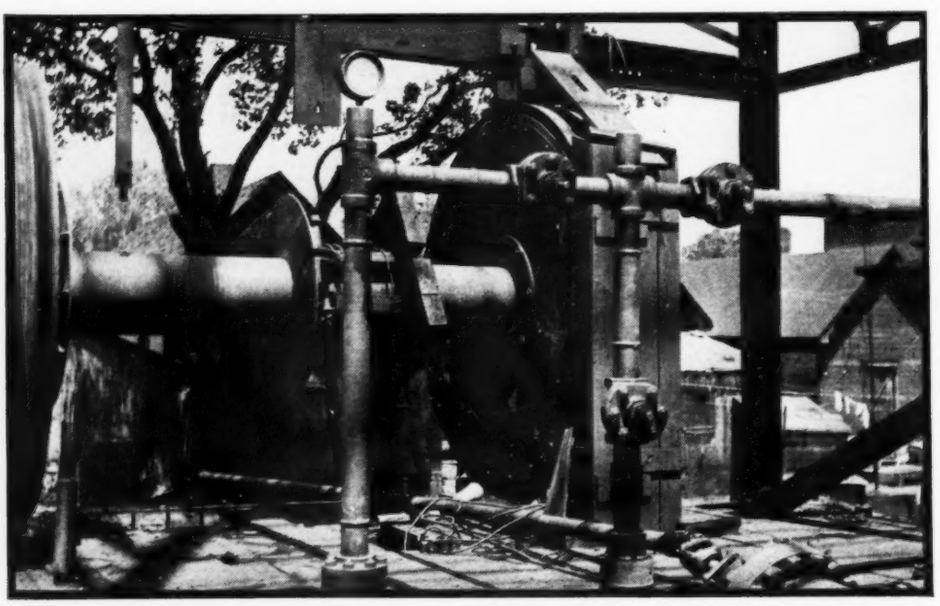
Intermittent flow is employed usually for small wells, where the injection of gas takes place at regular intervals, ranging from a few minutes apart to periods of several hours apart. This method has been employed during the past year in Oklahoma City, Seminole, East Texas, Raccoon Bend, Pettus, Sugarland and Yates fields, and at last reports was being employed in Argentine, Trinidad and Venezuela.

Discussion of Methods Employed

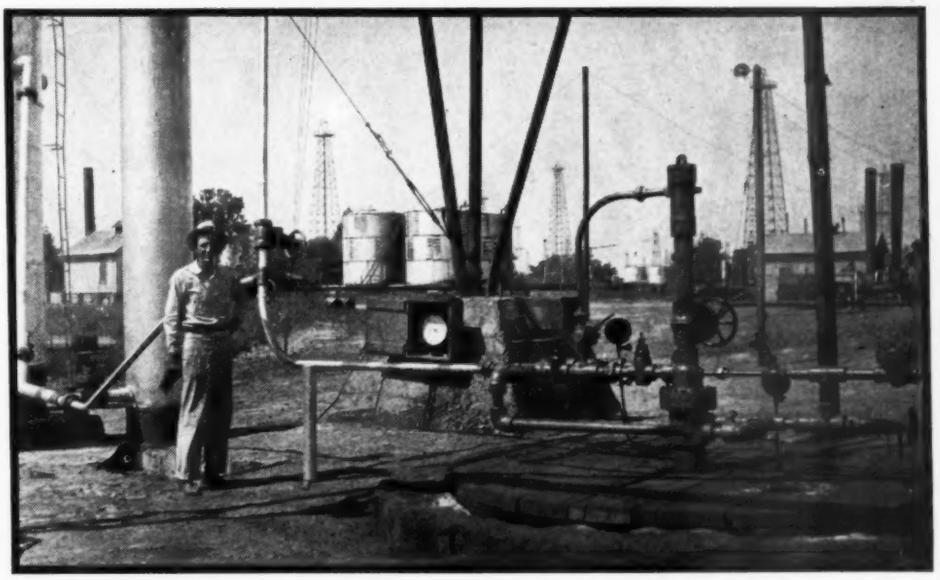
The method of air- or gas-lift operation most commonly employed is that of continuous flow, and dates back to the first recorded discovery of this principle by C. E. Loscher in 1797. The first successful recorded air-lift operation in oil wells seems to have been carried out in the Baku field, Russia, in 1899. This type of flow received a powerful stimulus from the enormous production obtained in the early years at Seminole, where it was found possible to lift several thousand bbl. per well per day from a considerable depth at a time when the price of oil was high.

It is possible to work out principles governing continuous gas-lift operations much more satisfactorily than in any other type of flow, and data obtained in the various fields where it has been employed are found to be of much value when adapting its use to new fields where conditions are much different from those in fields already exploited. However, the question of depth enters into the use of gas-lift to an important extent, and operators have found that without a thorough knowledge of the principles involved, experiences in shallow fields are misleading when the attempt is made to reproduce similar results in deep-seated fields.

For instance, in the Oklahoma City field, a large number of wells have been cased with 6⅝-in. O.D. casing and are provided with 2½-in. upset tubing for supplying the gas to the well. The flow of oil is through the annular space. Under these conditions there has been considerable disappointment in the results obtained. Under existing conditions in the Oklahoma City field, it is possible to lift through 6⅝-in. casing approximately the quantity of oil indicated in Table I.



Hook-up for gas-lift on an Oklahoma well, once rated at 100,000 bbl. per day



Hughes plunger lift on well in the Oklahoma City field

The quantity of oil possible to lift through 6⅝-in. casing at maximum capacity with bottom-hole pressure is 2750 bbl. With a bottom-hole pressure declining to 100 lb. the quantity lifted is reduced to approximately 50 to 150 bbl. per day, and if water encroachment under this condition of bottom-hole pressure has become 50 per cent, the quantity of oil that can be lifted is less than 25 to 75 bbl. per day, and the consumption of gas will have increased to more than 16,000 cu. ft. per bbl. of oil.

The operation of gas-lift under the conditions just mentioned of casing size and bottom-hole flowing pressure becomes expensive for continuous gas-lift flow, owing to the small volume of oil obtained and to the high lifting cost, especially if there is necessity for depreciating cost of compressor equipment. Unless a plant has already been installed under conditions that were more favorable than that of 100-lb. flowing pressure, the building of such a plant could not be recommended.

However, other methods of gas-lift can be employed under such conditions, such as intermittent flow, and costs will be reduced to a considerably lower point. An instance in the Oklahoma City field is known where a Hughes plunger lift was installed with 2½-in. tubing, in which the casing pressure was about 40 lb., the production was about 30 bbl. per day, and the quantity of input gas averaged between 1000 and 1500 cu. ft. per bbl. of oil; there was no water mixed with the oil.

In the case of a 9-in. casing provided with 3-in. tubing, the maximum capacity of clean oil at 100-lb. bottom-hole flowing pressure with continuous flow is approximately 900 bbl. per day, and the quantity of output gas would be approximately 5000 cu. ft. per barrel. The quantity of input gas would, of course, be less than the output gas, depending on the gas-oil ratio from the formation. Even with a production of 50 per cent water, it would be profitable to lift oil through 9-in. casing under bottom-hole flowing pressure of 100 pounds.

The type of compressor plant necessary to install in the Oklahoma City field for continuous gas-lift operation is rather costly, owing to the great depth of these wells and to the large quantity of oil that may be necessary to be produced per day from these wells. However, no other method is capable of equalling the performance of this type of gas-lift flow when large production is desired. The cost of equipment can be largely reduced on a per well basis if a plant can be installed to service a group of wells. The taking of potentials and producing the allowables can be handled in rotation among the group of wells serviced. This method is largely that employed in this field.

The makes of compressors that have met with most favor in the Oklahoma City field up to the present time are the Clark, Cooper-Bessemer, Ingersoll-Rand, Miller, and Superior compressors. Both two-cycle and four-cycle gas engines are employed for driving the Superiors, though the two-cycle engine has been in most demand. In most cases the compressors are direct-driven by gas engines, though some Ingersoll-Rand compressors driven by electric motors have been transferred from the Seminole field and have given good satisfaction, especially when the fact is considered that the operators were not certain that gas-lift would answer their conditions, which made it advisable to install these plants at an initial expenditure as low as possible.

Production in the Oklahoma City field is obtained by lifting the allowables as early in the month as possible and then shutting in the well in order that the disadvantage of carrying forward of back allowables be reduced to a minimum. This also gives the operator an opportunity to make any needed repairs to the compressor plant or to the wells after the production has been completed.

Periodic flowing of wells, such as is the practice in the East Texas field, makes for an unusual set of conditions. These wells are capable of producing several thousand bbl. per day and yet are prorated to an average of less than 40 bbl. per day. The fluid level in this field stands very high, bottom-hole pressures are, therefore, high, and the allowable production can be lifted through a small tubing in a short time. The practice in general use in the East Texas field is to run 2-in. or 2½-in. tubing and flow through the tubing as long as natural flow can be employed, that is, as long as the well will automatically start the flow each day, and make the allowable within a few hours at most.

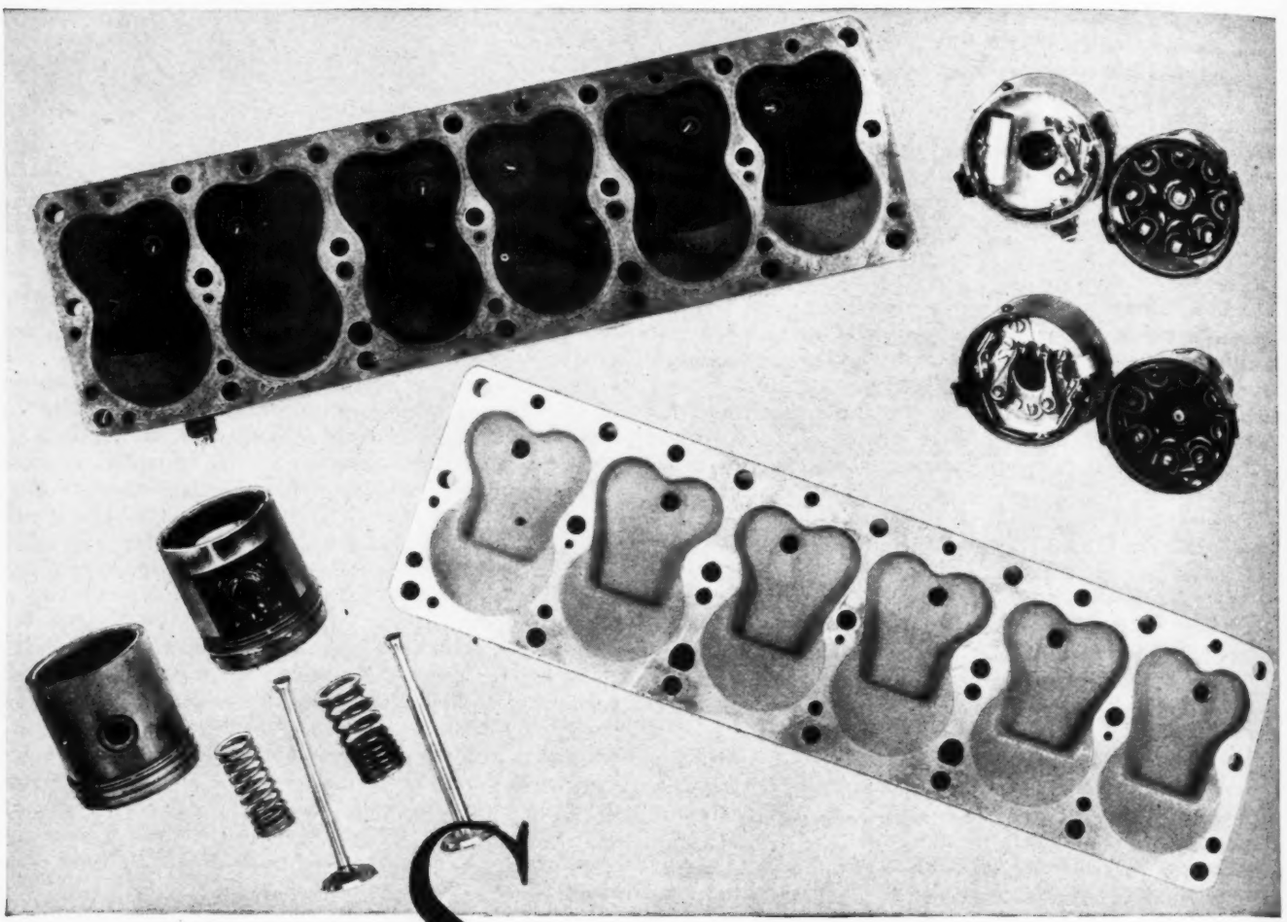
When the wells in the East Texas field give trouble in starting the flow each day, there has been a growing practice in inserting starting valves in the tubing spaced at intervals of about 300 ft., and flowing the well through the tubing

TABLE I

Approximate quantity of oil that can be lifted with continuous gas-lift flow through 6500 ft. of 6⅝-in O.D. casing with 2½-in. tubing under given conditions of bottom-hole flowing pressure.

Bottom-Hole Flowing-Pressure. Lb. per sq. in.	Bbl. of Clean Pipe Line Oil Lifted per Day	Cu. ft. of Gas Required to Lift One bbl. Oil
400	2,750	1,500
300	1,250	2,500
200	350-500	4,000
100	50-150	8,000
50	10-100	20,000

What Determines Size, Speed



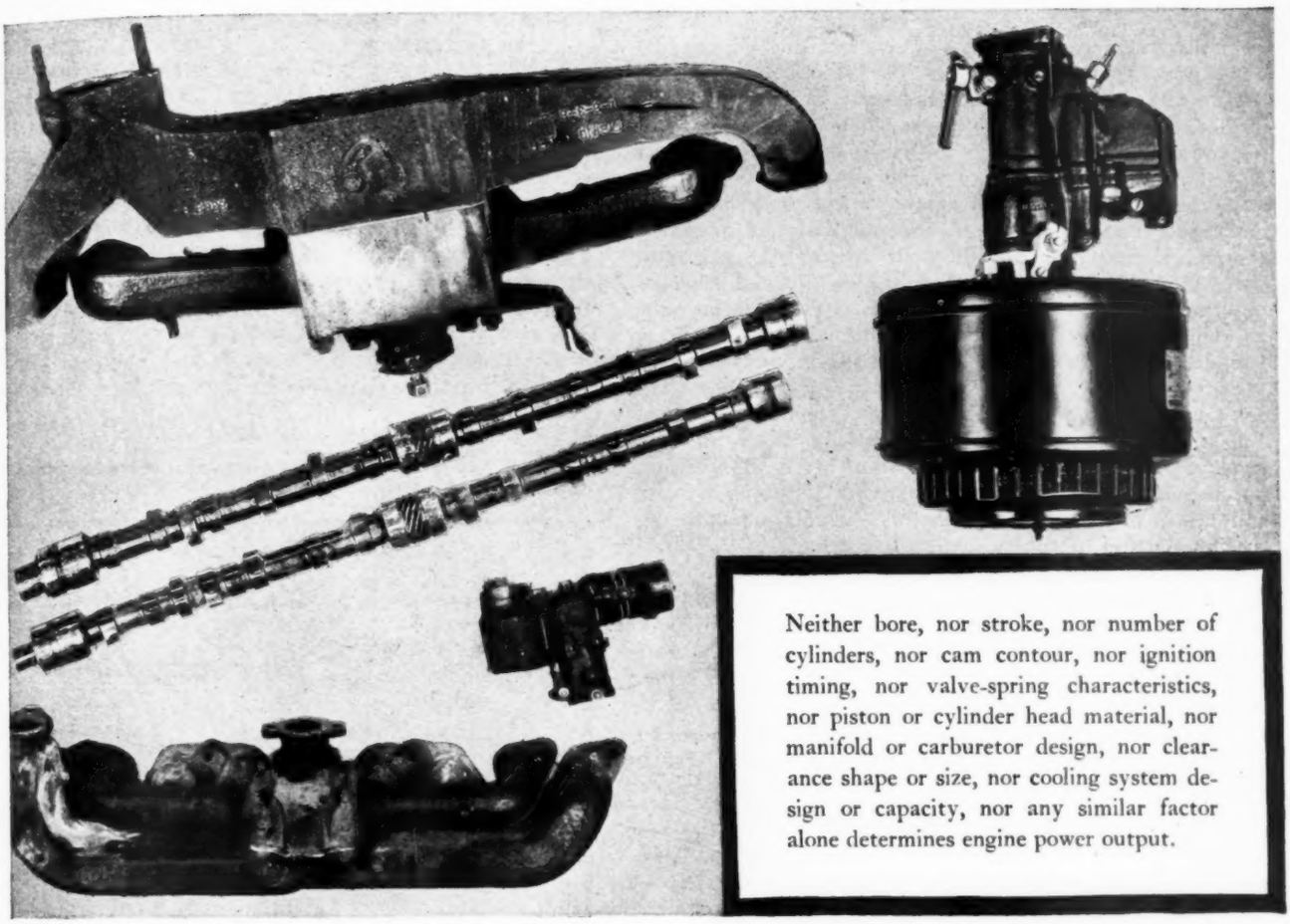
HOWEVER they are achieved—and regardless of how many component factors enter their achievement—an engine's *size*, its operating *speed*, and its working *pressure* are the three factors that affect power output. An increase in any one of these three factors will result in a proportional increase in power, provided the other two are not changed.

It may be possible to increase the compression pressure at which your engine will operate satisfactorily on a given fuel by changing the combustion chamber shape, or retarding the spark slightly, or using a high thermal conductivity material for cylinder heads, or applying less heat to the inlet manifold, or by abnormal cooling of valves, or by all of these methods. If it is found that any or all of these contribute to performance characteristics (without adding too many dollars to manufacturing cost), it would certainly seem advisable to make the necessary changes.

BUT—

When all this is done, it will still be possible to further increase the compression of the engine and develop a corresponding increase in power if fuel of better anti-knock value is pro-

POWER?



Neither bore, nor stroke, nor number of cylinders, nor cam contour, nor ignition timing, nor valve-spring characteristics, nor piston or cylinder head material, nor manifold or carburetor design, nor clearance shape or size, nor cooling system design or capacity, nor any similar factor alone determines engine power output.

AND PRESSURE DO

vided. Ethyl Gasoline has sufficiently high anti-knock value to permit the development by a given engine of substantially more power than can be produced by the same engine on any other generally available fuel.

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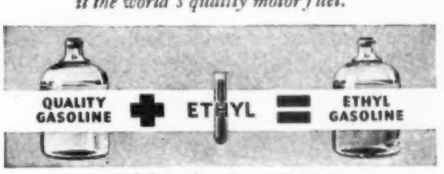


© Ethyl Gasoline Corporation, 1934

as long as sufficient gas is available for obtaining the allowable on natural flow. It has been found when using flow valves that sufficient gas collects in the annular space between the tubing and casing between flows to start the wells through the valves when the well is opened to the flow tanks. This method has been found to satisfy all requirements for many months after the wells would otherwise refuse to "kick-off" naturally.

In a few cases in the East Texas field it has been found that a stage in the life of the well has been reached where insufficient gas collects in the casing to start the wells, and small compressor units are installed on a lease where there is a group of wells. With this aid the wells are started whenever they give any trouble. The conditions are such in this field that the installation of such a plant with capacity of 250,000 to 500,000 cu. ft. per day is sufficient to handle five to ten wells, and in some cases will handle double this number of wells. The cost of such an installation at the present time for valves and compressor spread over a group of wells ranges from $750 to $1500 per well.

In the Government Wells field very little need for compressors has arisen, owing to the possibility of obtaining compressed gas for starting the wells from near-by gas wells.

An interesting development for shallow wells of 1700 ft. in depth is the periodic flowing of a group of eight wells on the Foster lease in the Somerset field, Texas. This lease was drilled by Alexander Boynton in 1926, and throughout its full life has been produced on gas-lift. The wells are cased with 4½-in. I.D. casing. Tubing of 1¼-in, 1½-in., and 2-in., provided with stage-lift valves, are now employed in some of the wells, while in others a pneumatic piston pump is installed with two strings of tubing, 2½-in. and 1½-inch. The wells are flowed once each day through the inner string of tubing.

Intermittent flowing of wells is usually employed after the production has declined to a low point where bottom-hole pressures are low. Under these conditions it has been found that production can be increased, and consumption of gas can be considerably reduced by flowing the wells intermittently.

Types of intermittent flow employed are as follows:

A.—*Through the annular space.* Gas injected through the tubing.

B.—*Through the tubing, without bottom-hole chamber.* Gas injected through the annular space. Includes the Hughes plunger lift.

C.—*Through the tubing.* Bottom-hole chamber employed, provided with standing valve. Gas is admitted through the annular space between the inner and outer strings of tubing.

Intermittent flow, method A, requires the minimum changes being made at the well, after discontinuing continuous flow. This method has been employed where production is as high as 500 bbl. per day, or even greater. In some instances where large quantities of water have invaded the sand, and where continuous gas-lift requires high consumption of gas and sets up serious emulsion difficulties, this type of intermittent flow has been found to reduce the consumption of gas; to increase the quantity of oil produced; and to reduce the cost of treating the emulsion. This method is employed in the Seminole and Oklahoma City fields.

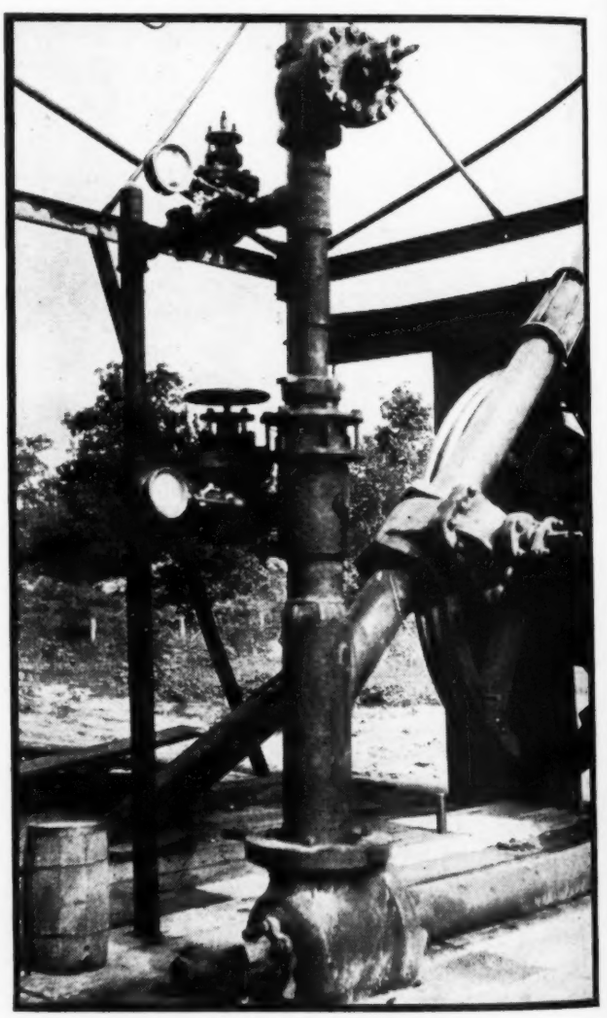
Method B is usually employed in connection with a valve of a type that opens and closes at differential pressures, or of a type, such as that employed in the Hughes plunger lift.

The Hughes plunger lift has made a considerable increase in the number of installations employed during the past year. In this method a small metal cylinder fitting close to the walls of the tubing, provided with a valve, makes trips the full length of the tubing. The oil is carried to the well head on the up-stroke, where it is discharged, after which the plunger drops to the bottom of the tubing for another load of oil. The plunger is lifted by being displaced by the gas supplied through the annular space between the tubing and casing. Tubing sizes mostly in use are 2-in., 2½-in., and 3-inch. In one instance tubing of 4-in. diameter is noted in a Venezuelan field. In some installations the tubing has been very carefully reamed to a given diameter, but of late, trials in the Oklahoma City field have indicated that the tubing can be supplied from the mills sufficiently uniform in diameter as not to impede the travel of the plunger. These plunger lifts are in use in the Pettus, Raccoon Bend, Sugarland, Oklahoma City, East Texas, Big Lake, Greta, Yates and Elm Grove fields. Some 15 installations of the plunger lift have been made in the Oklahoma City field up to the present time.

Consumption of gas in the plunger lift, even at fairly low bottom-hole flowing pressure is not excessive. Bottom-hole pressures of 40 to 250 lb. per sq. in. are common in the Oklahoma City field with the plunger lift, and gas input volumes range from 0 to 1900 cu. ft. per bbl. lifted. Some of the wells have sufficient gas with the oil that they are produced on the plunger lift without the aid of input gas.

Method C of intermittent flow has been employed where production has declined to a low point and where it is desired to reduce the consumption of input gas to a minimum. This method has been employed during the past year in various fields in California, Seminole and Burbank, also in various fields in foreign countries, including Argentine and Trinidad.

An efficient type of well hook-up for gas-lift flow in the Seminole area with 4-in. tubing suspended in 8¼-in. casing



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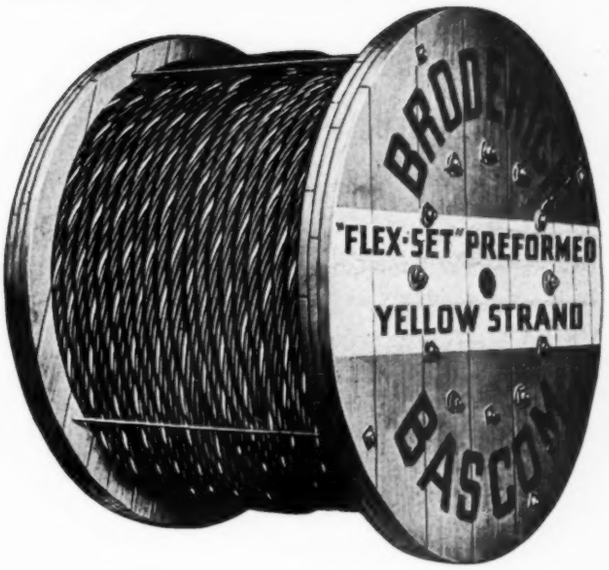

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Development of Technical Education for the Petroleum Industry

By H. C. GEORGE*
Head, Department of Oil and Gas Production, University of Pittsburgh

IN 1901, the United States produced 69,000,000 bbl. of crude oil, which was 41.4 per cent of the world production. By 1931, these figures were 850,000,000 bbl. and 62.1 per cent, respectively, showing over this period of 30 years an increase in the world production of 718 per cent. Over this same period, the increase in the demand for technically trained men in the industry was much greater than the increase in crude-oil production. This was because much of the increase in production was secured by the application of geology and physics to the finding of new oil fields and by the development of engineering methods and equipment incident to drilling and producing from much greater depths.

The growth of the petroleum industry was coincident with and chiefly due to the rapid development of the automotive industry, with the resultant great increase in the demand for gasoline, lubricants, and other petroleum products. These conditions produced an additional demand within the petroleum industry for men technically trained to handle the problems of transportation, storage, and refining.

During the first decade of the present century, the growing demand for scientists and engineers in the petroleum industry was met by increasing numbers of college graduates from the old established courses in chemistry, geology, and engineering. However, a need began to be felt for scientists and engineers specially trained for the petroleum industry. In 1912 the University of Pittsburgh established the first department in any university in the world that offered major work in petroleum geology and petroleum engineering. Other American universities entered the field in the following order: University of California, 1915; Stanford University, 1915; West Virginia University, 1916; Colorado School of Mines, 1921; Missouri School of Mines, 1922; University of Kansas, 1924; Louisiana State University, 1924; University of Oklahoma, 1924; Pennsylvania State College, 1928; University of Texas, 1928; University of Tulsa, 1928; University of Southern California, 1929, and Texas A. & M. College, 1929.

With reference to progress of petroleum education in Europe, I quote from a personal letter from A. Beeby Thompson as follows: "So far as England is concerned, the first petroleum course was started at Birmingham University in 1913, and in 1920 this department was liberally endowed by several large British oil companies. A few years later a petroleum course was started at the Imperial College of Science, School of Mines, South Kensington, London, and continued during the World War period. These are the only two universities in Britain where special petroleum training is arranged. On the Continent, so far as I am aware, there are no specially organized full petroleum courses, although in Imperial Russia, Poland, and Rumania petroleum subjects are incorporated in the curricula of the universities. The geological courses embrace the geology of petroleum in some countries where oil fields exist, and in chemistry the natural hydrocarbons and their treatment are a part of the regular study. Prior to 1915 I believe the only European country which could boast a regular petroleum course was England."

From 1904 to 1915, several American colleges and universities incorporated as part of some of the courses in chemistry, geology, and engineering, information dealing with the petroleum industry, without including the word petroleum in the name of the course. From 1904 to 1907, I gave instruction in petroleum production as part of the course in mining engineering at the University of Pittsburgh. The University of Oklahoma gave instruction in petroleum geology as early as 1907, as part of the regular curriculum in geology, and Chicago University gave instruction in petroleum geology as early as 1913. The University of California included, as part of the mining course, instruction in petroleum development and production, beginning in 1911.

During the period from 1910 to 1920, some chemists, geologists, and engineers who were teachers or were in state or federal government service or in the employ of oil or gas companies, gave lectures dealing with the oil and gas industries at some of our American colleges and universities. In this group I have in mind such men as Ralph Arnold, F. G. Clapp, V. R. Garfias, Charles N. Gould, Roswell H. Johnson, J. O. Lewis, L. C. Snider, and S. S. Wyer. The work of these men during this period and the interest developed by the U. S. Geological Survey and the U. S. Bureau of Mines in petroleum and natural gas technology were important factors in the development of higher education for the benefit of the petroleum and natural gas industries.

Beginning in 1910 the University of Southern California offered courses in petroleum chemistry. In 1913 the University of California began offering instruction in oil-field practice. In 1916, Oklahoma and West Virginia Universities began offering courses in petroleum geology and in 1917 Oklahoma University began offering courses in petroleum refining.

So far as I have been able to ascertain, major undergraduate work in petroleum refining has been offered by the following colleges and universities in the order named: Oklahoma University, 1917; Stanford University, 1920; Colorado School of Mines, 1921; University of Pittsburgh, 1922; West Virginia University, 1922; Missouri School of Mines, 1924; Texas A. & M. College, 1925, and Pennsylvania State College, 1932.

In addition to the American technical schools and universities previously mentioned, the following schools offer some courses dealing with the technology of the petroleum industry:

University of Colorado	Mass. Inst. of Technology	Oregon State College
University of Illinois	University of Michigan	Rice Institute
University of Kentucky	University of Minnesota	Wisconsin State Mining School
Lehigh University	Ohio State University	University of Wyoming

In addition to offering the regular four-year course leading to a degree in some branch of petroleum or natural gas technology, some of our state colleges and universities have shown the tendency during the past five or six years to branch out into short courses, extension courses, and correspondence courses. Although most of this instruction is not of college grade, it reaches a group which would not receive instruction otherwise, meets a great industrial need, and usually is being presented by men well qualified to give the instruction. Work of this character has been carried on by our state colleges for years in other industries, such as agriculture, dairying, and mining, and is a legitimate and worth-while function of our state institutions of higher learning.

In recent years some of the major oil companies have followed the policy, adopted many years ago by the electrical and steel companies and public service corporations, of giving a special training course for beginners in the industry. The course usually consists of both theory and practice and is generally required of both high school and university graduates, though the requirements for the two groups differ.

* Read before the annual meeting, A.I.M.E., New York, February, 1934.

Assembling pipe for submarine line at Monterey, California

Submarine Pipe Lines . . .

By G. E. HERRMANN, Chief Engineer
Associated Oil Company

IN California many of the oil fields extend into the Pacific Ocean and many of the trunk lines from the interior oil fields terminate at tideland. From these oil fields along the coast, and pipe line terminals, the oil is transported by tankers to the refineries or to local or foreign ports.

In most cases there are no wharves available to which the tankers could dock, and to construct and maintain them would be quite costly. Where no wharf exists the most economical method for loading the tankers is through a submarine pipe line extending from the shore to sufficiently deep water to accommodate the largest tanker.

These submarine pipe lines are constructed of steel pipe from eight inches to 16 inches in diameter and extend seaward for a distance of from 2000 ft. to one mile, depending on the depth of the water. On the outboard end of the submarine pipe line is attached a heavily constructed flexible hose which, when the tanker has been made fast for loading, is raised to the tanker's deck and attached to the deck piping. Moorings are placed near the outboard end of the submarine line to which the tankers tie up, holding themselves in position while loading. The oil is usually pumped from the shore tanks to the tanker through the submarine line; however, in one instance the loading is done by gravity. The shore tanks being located on a hill furnish sufficient head to load at the desired capacity without pumping.

The Associated Oil Company constructed the first submarine pipe line on the Pacific Coast in 1924 at their Ventura Marine Terminal. This line was built of 10-in. pipe weighing 45 lb. per foot. The lengths were screwed together and the collars welded. This line extended seaward about 3000 ft. and was pulled in place in sections about 1000 ft. long. The sections were welded together and a heavy steel river clamp placed over the weld. In 1925 this same company constructed two submarine pipe lines at their Monterey Marine Terminal in Monterey Bay, one being constructed of 12-in. pipe for crude oil and the other of 8-in. pipe for gasoline. These were built in the same manner as their submarine line at Ventura.

Since then other oil companies, seeing the practicability of such lines for loading tankers and appreciating their economic advantages over that of wharves, have constructed submarine lines along the California Coast between San Francisco and San Pedro.

During 1933 three new submarine pipe lines were constructed on the California Coast, all of which were built of 16-in. pipe.

In February, 1933, the Associated Oil Company replaced their 12-in. line laid in 1925 at their Monterey Terminal, the original 12-in. line having been broken when the mooring lines of a foreign tanker parted while the tanker was loading. This permitted the tanker to shift its position, putting sufficient strain on both the hose and submarine pipe line to cause them both to break.

In April, 1933, a 16-in. submarine line was laid in southern California, extending seaward about 3,300 ft. from the end of a wharf.

In December, 1933, the Associated Oil Company constructed the year's second submarine line, being obliged to replace their 10-in. crude submarine line laid in 1924 at Ventura, it having corroded through at a point about 200 ft. seaward from the high tide line, which point lay in the surf, thus rendering it impracticable to repair. The new line was constructed of 16-in. seamless steel pipe and on the outboard end was attached a 10-in. submarine hose. This line is approximately 3500 ft. from the block valve on shore to the outboard end of the pipe.

This 16-in. line was constructed of double random length pipe having a wall thickness of 9/16-in. and weighing 92.74 lb. per foot. The pipe was made up on shore in sections about 1100 ft. long, the lengths being welded together by

the oxy-acetylene process. The pipe was coated for about 1000 ft. where it extends through the surf with three coats of coal tar enamel reinforced with fabric.

The pipe sections were made up on the lower end of Ash Street in the City of Ventura, which street has a grade of approximately one and one-half per cent for about 600 ft. inland from the high tide line and from that point on the grade is about eight per cent. This change in grade required that a temporary earth fill be made at the break in grade for a distance of about 400 ft. to prevent placing too great a stress in the pipe when the sections were made up.

The launching ways were constructed of two 6-in. by 8-in. timbers about 12 inches apart, resting on 2-in. by 12-in. sleepers. These sleepers were placed under the joints of the 6-in. by 8-in. timbers and averaged about eight feet apart, the joints of the 6-in. by 8-in. timbers being staggered. On the 6-in. by 8-in. timbers were placed slides constructed of 2-in. by 12-in. lumber with 2-in. by 4-in. guides. These slides were placed 20 ft. apart. The sections of pipe were placed on these slides for launching, being held in place with wooden wedge-shaped chocks.

Pipe dollies were used for lining up and rolling the pipe when welding. By the use of these it was possible to make up each 1100-ft. section without an overhead weld.

The vertical bend in the pipe, due to the change in grade, did not interfere with rolling the pipe when welding the sections. It was essential that the sections be made up absolutely straight, and this was accomplished by use of a line-up clamp for holding the lengths together for tack welding. The first section was made up directly over the launching ways, the other sections were made up parallel thereto, permitting them to be rolled onto the ways by use of pinch bars. A sled was attached to the outboard end of the first section to keep the pipe from fouling on the floor of the ocean during the launching operation.

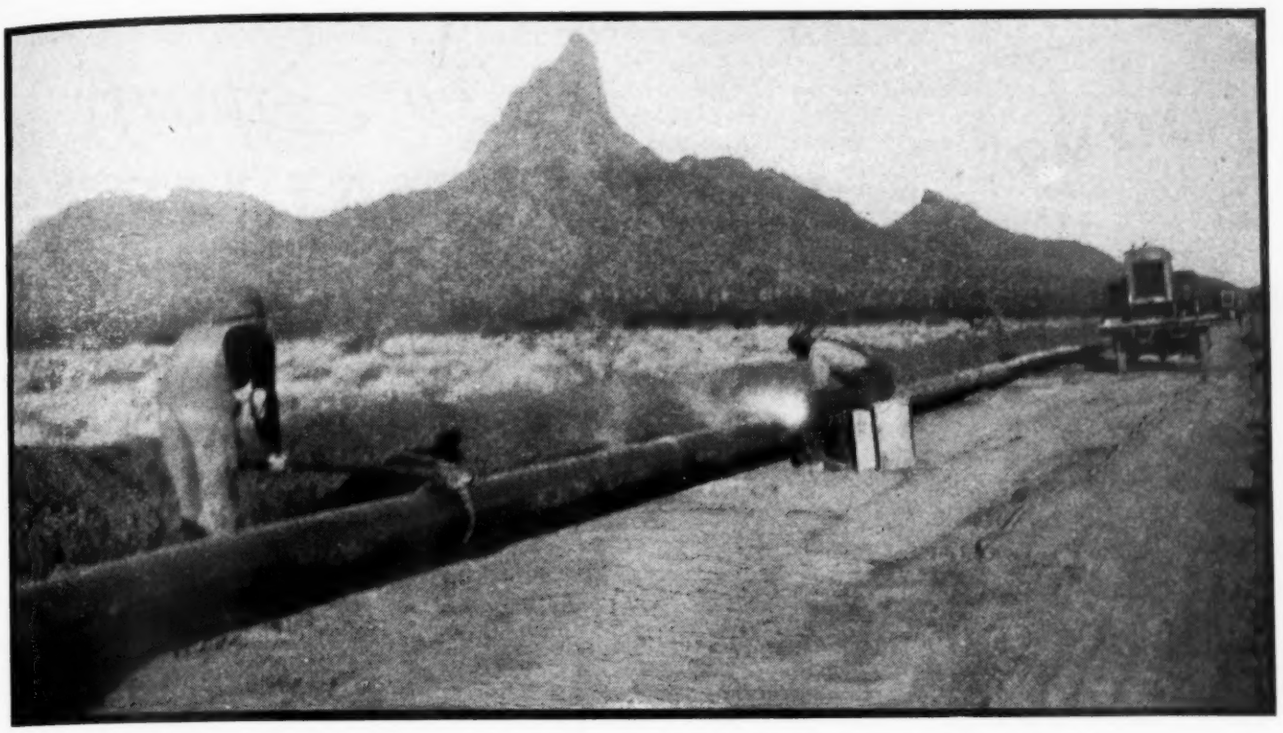
A towing clamp was fastened to the pipe about four ft. from the outboard end to which the towing cable was attached. The launching was accomplished by means of a towing engine aboard a barge anchored offshore in line with the launching ways. Some 75 ft. from the inboard end of each section was bolted a clamp with a link on either side. Deadmen were placed about 40 ft. on either side of the outboard end of the launching ways. A 1-in. steel cable 50 ft. long was fastened to each deadman, with a hook on the end of each cable. When the inboard end of each section approached the shore at the time of launching, the cables were hooked into the links of the clamp, which securely held the pipe in position until the following section was welded on. The outboard end of the first section was blind-flanged. After the entire line was pulled to its final resting place this blind flange was removed by a diver, thus allowing the pipe to fill with water, its own weight being sufficient to hold it in place.

An insulating flange to arrest any current flow was installed in the line about 200 ft. inshore from the high tide line.

During the launching operation, communication between the barge and shore was maintained by use of a semaphore on shore and whistle signals from the barge, as well as an air-operated horn at the semaphore, which was located just above the high tide line. In addition, a temporary telephone hook-up was installed between the barge and shore. This was connected to the permanent phone cable used for communication between the tankers when loading and the shore. This temporary telephone hook-up furnished uninterrupted communication throughout the entire period of launching of the new line.

Submarine pipe lines have proven to be the most economical method for loading tanks where no wharf or dock is required for handling other cargoes. They are by far the less costly to install and maintain, when compared with a wharf or dock, and usually an annual overhauling of the mooring buoys and submarine hose is sufficient for efficient operation.

Cleaning pipe preparatory to painting, Ventura, California



« Electric welding on Douglas-Phoenix line of Western Gas Company »

Review of Progress and Trends in Pipe Line Systems

By FRANK H. LOVE

EFFORTS at pipe line advancement during the last year were largely directed toward greater economy and operating efficiency. Construction of lines longer than 100 miles were few, but numerous gathering systems were laid, as well as short connecting lines necessitated by the opening up of new fields through increased wildcatting activity. While none of these fields has as yet developed to major size, a number show possibilities.

The oustanding construction project of the year was the Iraq Petroleum Company's 1200-mile line by which oil will be transported from the Iraq fields to the Mediterranean Sea.[1] Construction work has been in progress for more than a year and it is expected that the first oil will flow through the carrier sometime next fall. Because of the length of the line and the topography of the country traversed (virtually every known soil condition being encountered) the work is of particular interest from an engineering standpoint.

Figures released by the American Gas Association indicate that the natural gas industry was not affected by the depression to the extent that some others were, which explains the preponderance of activity in the construction of natural gas transportation lines as compared to the building of oil lines. The largest gas line was the 216-mile 10¾-in. line of the Western Gas Company's in Arizona, extending from Douglas to Phoenix, via Tombstone, Tucson, Florence and Mesa.[2] This was a continuation of the distributing system of the Western Gas Company's parent organization, the El Paso Natural Gas Company. Crossing mountains and desert, laying of the pipe required the employing of special engineering practices. Variations in elevation necessitated more than 4000 cold bends; erosion was a serious problem, the foothill country being cut repeatedly with washes and arroyas, some of which could not be spanned and the line had to be laid beneath. A wide expanse of lake bed having a salt floor was encountered and, to avoid the corrosive effects, a by-pass line was laid underground. A hot enamel coating was applied to the pipe to guard against electrolysis.

Gasoline Carriers

Construction of new gasoline transmission systems was not so widespread as many had expected. Various reasons for this have been advanced, some believing that the uncertainty created by the proposed pipe line divorcement measure was responsible, others being of the opinion that existing lines are amply caring for all requirements. Facilities were added to gasoline carriers already operating.

The longest new project was the 80-mile 6-in. line of the Pure and Sun companies from Toledo, Ohio, to Detroit, Michigan, completed July 13.[3] This line was characterized by several distinctive features. It was constructed on one of the narrowest right-of-ways in existence, an 8-ft. strip

[1] "Transportation a Major Problem in the Construction of the Iraq Line," *The Petroleum Engineer*, July, 1933, Vol. 4, No. 11.

[2] "Longest Gas Line Project of Year Nearing Completion," by J. F. Weadock, *The Petroleum Engineer*, December, 1933, Vol. 5, No. 3.

[3] "Toledo-Detroit Gasoline Line Completed," *The Petroleum Engineer*, August, 1933, Vol. 4, No. 12.

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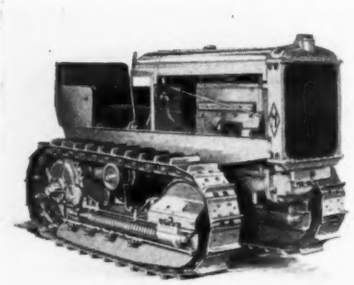

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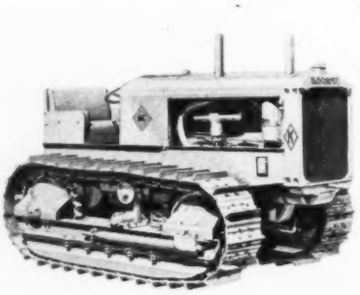

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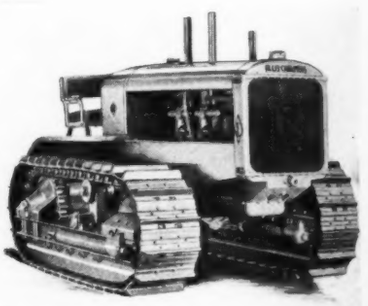

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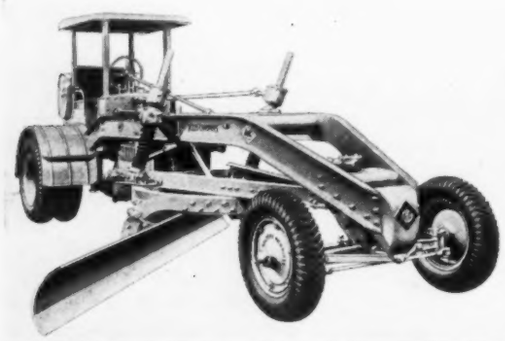

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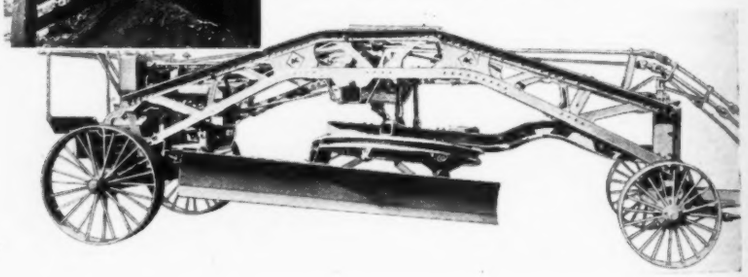

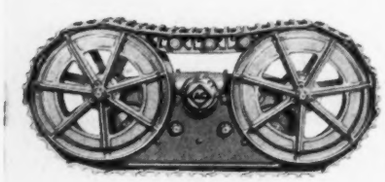

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paralleling the Toledo-Detroit highway. For its length, the line has an exceptionally large number of tunnels, the crossing of numerous highways and railroads accounting for many, while others were necessitated by a stipulation in the contract requiring that all trees be carefully handled and no roots larger than an inch in diameter be severed. It was necessary to tunnel beneath such roots, a special boring machine being used that drilled the hole and pulled the pipe through the tunnel in one operation. A system involving the use of levels and guides was the chief means of aligning the machine.

Station Operation

In a discussion of pipe line developments, the trend in station operating practices and equipment is of primary interest—the trend for field boosters as well as main line stations. Larger investments were made in the installation of field station equipment a few years ago than are made today. Then considerable sums were expended for concrete floors, foundations, reservoirs, buildings, etc., items that could not be salvaged when the field played out and it became necessary to dismantle the station. In addition to the large initial cost, such stations had the further disadvantage of being expensive to operate, and the time required for construction (when time was at a premium) also worked to its disfavor. Various means have been developed to remedy these conditions and increase station flexibility. The Bullock Pump Station of the Stanolind Pipe Line Company, Limestone County, Texas, is an outstanding example of what can be accomplished in this respect.[4] From this station, one of the most important key or control centers on the company's system, crude can be delivered either through the Mexia, Texas, trunk line station, approximately six miles away, or directly into the trunk line by by-passing the Mexia station. Such flexibility is acquired by use of a high-speed high-pressure pump driven through a gear increaser by a high-speed Diesel engine. Although originally built many years ago, this station was recently remodelled to correspond with the modern trend. The equipment, being of light weight and small overall size, readily lends itself to dismantling.

Electric motors for driving centrifugal or reciprocating pumps also have come into wider use as gathering equipment.[5] A station thus equipped affords flexibility, and, at the same time, is readily portable. Where purchased power is not available, or power rates are too high for economic use, Diesel-engine-driven generators are now occasionally being installed. While electric-powered stations have been confined largely to boosters in the past, their use on main line units is increasing. The Atlantic Pipe Line Company's stations at Zavalla, Mount Enterprise and Silsbee, Texas, have been studied with considerable interest.

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[4] "How Flexibility of Field Station Was Improved on Stanolind Pipe Line System," *The Petroleum Engineer*, October, 1933, Vol. 5, No. 1.

[5] "Pipe Line Operation at Varying Capacities With Motor-Driven Pumps," by G. R. Prout, *The Petroleum Engineer*, April, 1934, Vol. 5, No. 7.

« View of Diesel-driven station on Texas-Empire System in Missouri »

Tapping machine used in connection with line-clearing process

In the fall of 1932 the Atlantic introduced to the industry the first practical application of electric generators, direct-driven by internal combustion engines, for supplying power to operate centrifugal pipe line pumps.[6] The original installation was at Zavalla, Texas, and its success prompted the Atlantic to build two other such stations during the past year, at Mount Enterprise and Silsbee, as well as enlarge the Zavalla plant. Station pumping equipment consists of three 340-hp. solid injection Diesel engines, developing 400 r.p.m. and direct-connected to fly-wheel type generators of 225 kw., 400 r.p.m., with a direct-connected exciter on each shaft of 20-kw. capacity operating at 125 volts. The generators are arranged for parallel operation, and the exciters so arranged that one can be used for excitation of all the generators and any one exciter can be employed for auxiliary purposes in the power station. Two 350-hp. induction motors are situated directly back of the switchboard, their drive shafts passing through the wall to connect with multi-stage centrifugal pumps. Unusual flexibility is gained by having no one prime mover tied up with any one pump. These stations are interesting departures from previous designs and their influence upon future installations is being closely watched.

Another pump design departing radically from previous standards is that of the Rannett pump.[7] Original installations of this pump were made on the Great Lakes Pipe Line Company's system in the spring of 1933, and with their practicability established, that company this spring added two units of the same type. These pumping units are electrically operated and constructed so that they can be installed in the open with no housing. The unit consists of either a 700-, 400- or 200-hp., 3-phase, 2-pole, 2300-volt, 3600-r.p.m. induction motor direct-connected to an 8-stage centrifugal pump. Motor and pump are connected through a central spacer section, with the stator laminations inserted in a double-walled housing. The fluid being pumped enters the double-walled section of the motor from the pipe line, which is aligned with the shaft of the unit. Inlet to the motor is at the top and bottom at the outboard end, and the gasoline flows spirally and laterally around the motor, leaving at the top on the inner end, over the spacer section to the pump intake. The complete unit weighs approximately 18,000 lb. and is easily transported and readily installed.

When the Phillips Pipe Li pany laid its gasoline trunk line from the Texas Panha to St. Louis, Missouri, gas engines were employed for the first time as prime movers to drive pipe line pumps. Now the Phillips company has adopted the same type of prime mover for its crude oil line.[8] The use of a comparatively slow-speed engine to drive centrifugal pumps through gear increasers was an important demarcation, and their use in transporting crude is another step toward their widespread usage. When the Phillips organization completed its 210-mile 8-in. line from the Oklahoma City field north to Thrall, Kansas, to connect with the company's line to Kansas City, Kansas, two stations were equipped with gas engines as prime movers. At the station located on the northeastern edge of the Oklahoma City field (and which is typical of the other station) the pumping equipment consists of five gas-driven units and two electrically operated pumps. The latter are of 165 hp. developing 250 r.p.m. Between the engine shaft and the gear increasers flexible couplings are placed, which serve to compensate for a small degree of misalignment and also, through their resilient elements, take up the non-uniform rotation of the engines and prevent such rotation from reaching the pumps. The engines are operated on residue gas, the fuel being introduced into the prime mover after passing through low-pressure regulators.

Automatic station operation, of ever-increasing interest, has been the field for considerable experimental work.[9] One of the most recent developments is in connection with the sump, necessary in an automatic station to catch leakage from the pumps caused by leaky gaskets or stuffing boxes. A liquid level control has been provided to start the motor when a maximum level is reached and to stop the motor when the liquid is pumped down to a minimum level. A second automatic sump control indicates excessive leakage from the pumps such as occurs when the stuffing-box packing or a gasket blows out. This control stops the main motor pump and signals to the control plant when trouble occurs. Bearing and stuffing-box temperature controls also function to stop the main motor and signal trouble when excessive temperatures indicate insufficient lubrication or other difficulty. Since the stuffing box of the pump is a fire hazard, one pipe line company has equipped a station with fusible links located near the ceiling of the pump room, directly above the stuffing box. Should a fire break out the heat would melt the links, closing a switch that would shut down

[6] "Diesel Engine Powered Electric Generators Used Efficiently in Modern Pipe Line Pump Station," by L. M. Goldsmith, *The Oil and Gas Journal*, January 11, 1934, Vol. 32, No. 34.

[7] "New Rannett Stations added to Great Lakes Line," *The Petroleum Engineer*, April, 1934, Vol. 5, No. 7.

[8] "A Gas Engine-Powered Crude Oil Pipe Line Station," *The Petroleum Engineer*, January, 1934, Vol. 5, No. 4.

[9] "Automatic Control as Applied to the Gathering and Pumping of Crude Oil," by W. H. Shields and T. D. Williamson, *The Petroleum Engineer*, May, 1934, Vol. 5, No. 8.

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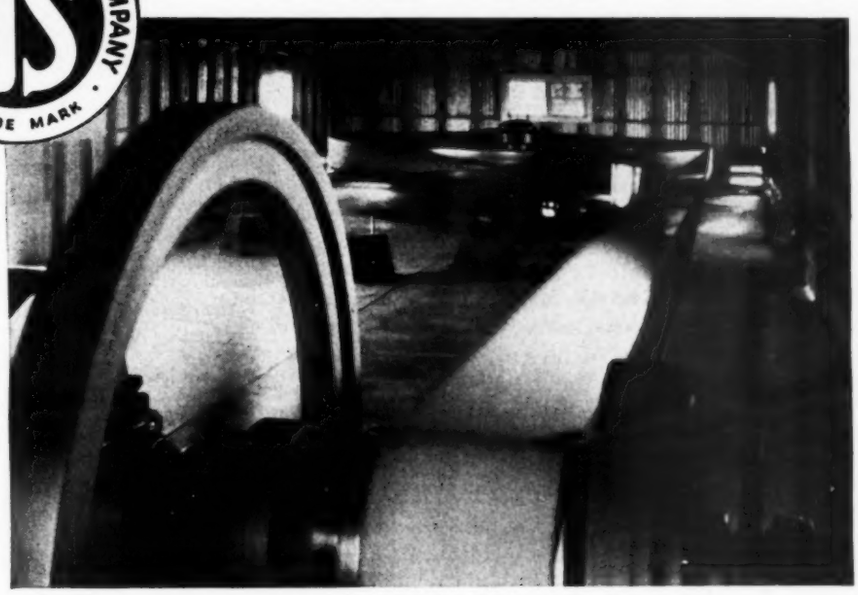

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the station and transmit a fire signal. When these automatic devices are applied to booster stations not having tankage, the main motor-driven valve controlling the stream of oil into the station is automatically closed to divert the oil from the station through the main line where check valves are normally installed, which are open when the main motor valve closes but which, under normal operation, remain closed due to the discharge pressure of the station pump when it is in operation. These latest automatic control features have been tested and proven commercially successful.

Heat Exchangers

Heat exchangers for cooling jacket water from Diesel engines are recent important developments and during the year there has been an increasing tendency on the part of pipe line companies to abandon existing open-type cooling systems in favor of the more modern exchangers. The entirely successful exchanger system consists of a shell and tube arrangement through which the hot water passes countercurrent to the crude oil being pumped, the oil acting as the cooling agent. In first installations of this type the exchangers were located in the suction lines to the pumps, but more recently high-pressure exchangers have been employed and placed in the discharge line.[10] The simplicity of this method has certain advantages: booster pumps are not required, and the filling of the pumps is not retarded. In some localities, and where steel tubes are used, corrosion has proved to be a serious problem. Treating the water has been found an effective means of retarding such corrosion. Hydrated lime is used to hold the hydrogen-ion concentration of the water above 8.4 and sodium chromate serves as a rust inhibitor. The latter should be used in quantities of 0.025 to 0.035 per cent. The reduced installation and maintenance cost, as well as the advantage of portability, has been largely responsible for the heat-exchanger system's popularity.

Corrosion

Pipe line engineers are continually conducting research and devising new methods of combating corrosion, and experiments of the year have added to the fund of knowledge along that line. Since the annual cost to pipe line companies for digging up and reconditioning pipe attacked by corrosion resulting from electrolysis is estimated by the United States Bureau of Standards to exceed $140,000,000 extensive research work has been done in that direction and much accomplished. Progress has been made in employing electricity in what is known as "cathode protection."[11] Electrolysis results from the flow of direct current off the pipe and the theory of "cathode protection" involves the lowering of the potential of the pipe below that of the surrounding soil to a degree sufficient to cause the current to flow on to the pipe. This is accomplished by use of a rectifying station consisting of a transformer for stepping down the purchased power to 110 volts and an entrance switch and multiple-tap transformer (located inside the station) for stepping the voltage down from 110 to that required. The voltage is then rectified by a bank of Rectox units to direct current. The negative terminal of the d.c. is connected to the pipe line and the positive terminal to a ground bed. Connections are made with a 300,000-cir. mils cable to eliminate voltage drop. The ground bed is situated 500 ft. from, and at right angles to, the pipe line and consists of 50 lengths of 6-in. cast-iron pipe ten ft. long set vertically in the ground and bonded together. The rectified current is forced out of the ground bed into the soil, through which it passes to the pipe line to complete the electrical circuit. The current enters the pipe at points where the coating is defective and returns to the station through the pipe and connecting cable. The amount of current required for full protection to the pipe is in direct proportion to the number of abrasions in the pipe coating and the electrical resistance of the coating itself. Mitigation of electrolysis by this means has been developed to a point considered satisfactory and has been adopted by a number of pipe line companies.

Welding Without Backing-Up Ring

An important welding development was that of making a shielded-arc electric weld on a plain end butt pipe joint without the use of a backing-up ring.[12] The first time a weld of this nature was employed on a major project was in the construction of the Phillips Pipe Line Company's carrier from Oklahoma City to Thrall, Kansas. Previously it had been considered necessary to have a backing-up ring for electric welding in order that the first bead would not burn through the pipe and cause icicles to form on the inside. Experience on the Phillips line, and others subsequently, has proved such is not the case. Economies effected by this method of welding have caused it to grow in favor. In addition to increasing welding speeds on new line, it is now possible to electric weld second-hand pipe recovered from old lines laid as screw or butt joint acetylene-welded lines. Heretofore welding of this kind of pipe had been confined to the acetylene method. The practicability of such a process was more fully demonstrated when the Sinclair-Prairie Pipe Line Company laid a 70-mile section on its transmission system between Singleton and Teague, Texas, the pipe having been torch-cut and salvaged from an old line in Oklahoma.[13] The pipe used in laying this line was 12¾ in. in diameter, with a ⅜-in. wall, and while the ends were not quite smooth, no difficulty was encountered by the welders in making the arc welds. Due to the feather edge and the necessity for spacing the pipe as closely as possible, considerable time was consumed in making the ends fit. However, the welders on the firing line made exceptionally good speed.

New Methods of Making "Cut-ins"

Quite frequently it is necessary to "cut-in" a line for the purpose of making a loop, or when new station yard lines are laid or a new manifold installed. Before doing so it is necessary to clear the line of oil. The expensive and wasteful method of digging a pit or making a dam to impound the oil on the ground is giving way to more scientific procedure. W. G. Heltzel, general superintendent of the Stanolind Pipe Line Company, and C. M. Scott, Jr., chief engineer of the same company, are two of the men responsible in a large measure for progress in this connection.[14] They evolved two methods of displacing oil from a line without loss of fluid. One method involves displacement of the oil by air; the other is accomplished by pumping the oil from the trunk line into a parallel line, when one is available, and there impounding it until the "cut-ins" are completed. Special equipment has been devised by J. E. Polston and A. M. Hill, of the Stanolind organization, for use in connection with the latter process. These methods, while not originated within the past year, have been developed to a higher degree of efficiency during the period.

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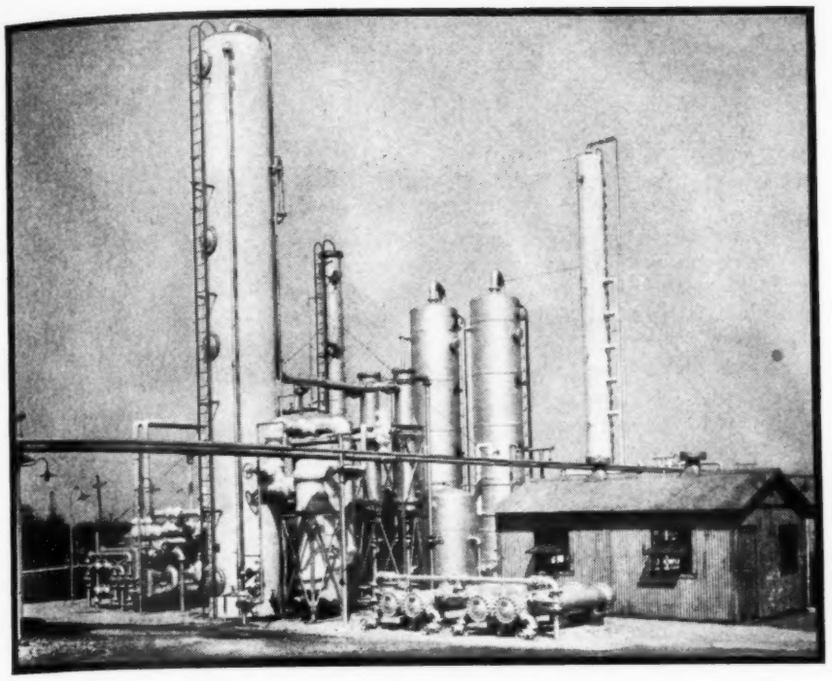
[10] "Crude Oil Pipe Line Transportation," W. G. Heltzel, General Superintendent, Stanolind Pipe Line Company, before A.S.M.E., Tulsa, May, 1933.

[11] "Electrical Mitigation of Pipe Line Electrolysis," by R. T. Falkenberg, *The Petroleum Engineer*, March, 1934, Vol. 5, No. 6.

[12] "Butt Joints Without Chill Bands Featured Phillips Line Welding," by H. C. Price, *The Petroleum Engineer*, June, 1933, Vol. 4, No. 10.

[13] "Cutting Up Old Pipe Lines," by N. E. Wagner, *The Petroleum Engineer*, November, 1933, Vol. 5, No. 2.

[14] "New Engineering Ideas Incorporated in Station Improvement," *The Petroleum Engineer*, May, 1934, Vol. 5, No. 8.



Natural gasoline absorption plant in the Oklahoma City field

By
EMBY KAYE
Vice President, Skelly Oil Company, Tulsa

Observations on Natural Gasoline Developments

AS 1933 came to a close, natural gasoline manufacturers turned buoyantly forward to the bright future immediately ahead and closed the books on its history written in crimson for the past few years; or so it thought. For, in the fall of that year, natural gasoline went into abrupt and eager demand again, and its market price came up from behind (it had a long way to go) and, before the year's end, passed that of motor fuel. There was actually a substantial shortage of natural gasoline in spite of additions to the supply that the improved prices were making available.

It is strange how casinghead gas, and even natural gas, seldom goes begging for a gasoline plant. For even after a dismal record of three or four years, and in the face of what appears to be a hopeless immediate future, natural gasoline plants have been built.

Conservation Plants

In East Texas the earlier plants were installed by producing companies solely for conservation purposes. Either it was intended to utilize the fuel for operations or to return gas to the sands to conserve them, to preserve the reservoir energy. It is said that Humble Oil & Refining Company's plants were of that character. They were of the straight compression type, and, because of the high reservoir pressure, at least three stages of compression were required. The compression cost was thus high. The liquefied gas or gasoline contained so much fixed gas that excessive fractionation equipment was required.

Another factor that tends to increase the investment and operating expense is the severe proration of the field. With a relatively low gas-oil ratio in the first place, many wells are required to produce enough gas to justify—if at all—the expectation of a profitable enterprise. The cost of a pipe line to reach to these wells would, with the other heavy costs, tend to make few plants commercially feasible.

Later plants, particularly those built within the past year, have been of the conventional low compression type for gas gathering and absorption process for extraction. In either case, however, very few pieces of equipment were used that were not second-hand. The Seminole field particularly yielded a large quantity of equipment no longer needed there. The low cost of second-hand equipment may largely explain the "economics" of these East Texas plants.

Wanton Waste in Texas Panhandle

For better or for worse, there are now 14 plants that produce 126,000 gal. per day of natural gasoline, which the motoring public must eventually consume.

But if this East Texas gasoline is an unwanted child born of wedlock, the new natural gasoline brought into production in 1933 and to this writing, in the Texas Panhandle, is a child born of rape. If the former had to be produced as a conservation matter, the latter is the result of the very negation of conservation. The wanton waste of billions of cu. ft. of natural gas for the extraction of the pittance yielded from the gasoline can never be excused, except as selfishness and greed.

The development of the additional supply of 150,000[1] gal. of natural gasoline by means of stripper wells in the Texas Panhandle, without facilities for storing and depending upon a from-day-to-day market, is at the least one of the contributing factors making for low prices for this commodity. In the writer's judgment, these plants should be shut down or their production greatly reduced; however, that is another story.

[1]Bureau of Mines' figures for February, 1934, show an increase of 196,000 gal. daily in natural gasoline production as against the same month in 1933. The additional production (approximately 50,000 gal. over the estimated stripper plant yield) results no doubt from the processing of dry gas by other gasoline plants as a protective measure against the depletion of their gas by stripper plant operators who take much more than their fair share in relation to their acreage holdings.

In the main, the new Panhandle plants depend for their gas upon a limited number of gas wells. Depending entirely upon rock pressure, the plant has no gas compressor unit. For the same reason, high rock pressure, hence small dimension, low-cost pipe lines are required. Again, the volume per well being so great, only a very limited gathering system is required.

At the high pressures at which these plants are operated, the absorption equipment required is necessarily reduced. In other words, the capacity per unit of volume is greatly increased, which in turn means lower investment and lower operating costs. Some of these stripper plants do not have treating plants or fractionating units. They sell their raw output to other manufacturers who have these facilities. In other words, these plants are "stripper plants" indeed, sort of "gadgets" as it were, that you stick on to a gas line.

Almost from inception, a "casinghead plant" was considered a "scavenger of waste," a conservator of the oil fields. The plant was built to save gas both for its gasoline content and for its fuel value. In fact, many plants were built primarily for the latter purpose. Even at the present time, wells are operated with that pressure on the sand or on the traps dictated by the requirements and conditions most conducive to the production of crude oil. That situation has been unusual where the producer of oil allowed sufficient pressure over a period of time to permit of gathering the gas without vacuum pumps or compressors on which a vacuum was maintained. An ultimate estimate of a gasoline plant was bound to include allowance for a compression unit (30-lb. pressure) variously estimated at from $8000 to $10,000 per million cu. ft. of gas. The cost of compression to that pressure available to the stripper operator would be several times this amount.

Destructive Competition

The effect of low-cost gasoline on a none too ready market is obvious. The one way to move excess production is on a price basis. The fact is that this operator can make a profit almost at any price; but the manufacturer of natural gasoline, on the normal basis, must dig down into his reserves or shut down his plant.

Let us take a situation the writer has in mind.

On the one hand is a gasoline plant of the conventional type, connected to some 200 wells scattered over thousands of acres, with over 50 miles of pipe lines for gas gathering, residue gas, and water services, over 50,000,000 cu. ft. of compressor capacity, a 1600-hp. electric generating plant, low-pressure absorption equipment, etc., stabilizing, treating, and loading facilities representing an investment of $1,250,000 and producing 35,000 gal. of gasoline. On the other hand, a few miles away, is a stripper plant, processing over 100,000 million cu. ft. of gas from less than a dozen wells in a concentrated area, and producing in excess of 35,000 gal. of gasoline, with no stabilizing, treating, or transportation facilities and costing at the outside less than 10 per cent of the plant first described.

The writer is holding no brief for the vendors of mechanical equipment who missed the sale of millions for equipment nor for the men who might have been employed. This is simply part and parcel of the history of the natural gasoline industry during the past twelve months. This production benefits a few against the interest of the many, and should not be allowed in the light of today's economic theories, where limitations are in divers ways placed upon production. This is quite apart from the questions of gas waste and the depletion of gas energy from the Panhandle oil formations, on the basis of which it is anticipated that the Federal Courts will outlaw stripper plants or greatly limit their use of gas.

Notable Development in Gulf Coast

An interesting gasoline plant development of the recent past is that of Danciger on the Gulf Coast southwest of Houston, near the town of Bay City. The gas is produced from a 7000-ft. horizon and yields approximately 1/3 gal. of natural gasoline, ½ gal. of water-white kerosene per 1000 cu. ft., and some gas oil. Several wells are in production.

High-pressure absorption equipment built by a Tulsa manufacturing concern was used in the plant. Absorption oil is produced right from the well. Since a natural pressure in excess of 2000 lb. is available, it is not contemplated that compression machinery will be required in this plant for many a year. There is considerable doubt whether or not gas of this character will be allowed to be produced unless a market is found for the stripped gas. It is likely that with the location of large chemical plants on the Gulf Coast, considerable gas will be marketed through such channels.

In any event, this type of gas production is not to be confused with ordinary natural gas of low liquid content or with gas produced from a structure connected with oil-producing horizons. The writer is not disposed to say that there are enough differences to justify gas production from this field. It is more than likely, however, that from an exploration standpoint Danciger and Skelly, who have production in an adjacent structure, should at least be allowed to test the area to determine whether oil will not eventually be produced from these horizons.

Recent Plant Installations

In Oklahoma, Skelly Oil Company is completing a compression plant in the Little Chief field, the southeast extension of the Burbank field. Gasoline will be piped to its large Lyman plant, which serves its Burbank leases. There it will be further processed and marketed.

More or less of a unique feature of this plant is the type of condensing-rectification equipment employed. This is largely a development[2] of a Tulsa engineering concern, which has employed similar designs in connection with refinery vapor recovery systems and in the revamping of several old natural gasoline plants processing a settled volume of gas. The proration of this field and the character of the casinghead gas make this process particularly available.

The direct rectification process (first described in these pages in the September, 1930, issue) as employed in this plant is a dual column design in which the first column is operated at approximately 300 lb. and the second column at from 115 to 250 lb., depending upon the grade of gasoline desired. Any grade from 9 to 26 lb. can be produced with practically complete pentane removal, and with sufficient butane to enable the maximum gasoline yield of any grade.

Carter Oil Company is also building a two-unit compression plant in this field, while over nearby, in the Grayhorse district, on what is known as the Naval Reserve lease, Phillips is building a sizable compression plant with a "tail" absorption unit, the gasoline to be piped to its Burbank No. 2 plant.

As has been the case with all Burbank gas, the present production represents a sweet gas rich in the fractions that produce natural gasoline. While the present flow is necessarily curtailed due to stringent proration of the crude oil production, the gas represents a needed reserve for the plants

[2]Numerous claims involving this process have been allowed to Petroleum Engineering Company.

of the several companies. Incidentally, the gas is being made available to these companies largely through facilities abandoned by the decline of casinghead gas production in other fields. The utilization of this gas is in the truest sense a conservation measure. It is worth noting that the propane and butane not marketed as such will find their way back into the producing formation, where for years excess light ends from Burbank plants have been returned by a number of the gasoline manufacturers.

Few other plants have been constructed in the past year. Grimes Gasoline Company from Tulsa has completed a conventional absorption plant in Michigan to process 2,500,000 cu. ft. of 1¾ gal. (per M) gas. In western Kansas, Skelly Oil Company has completed and put into operation at Cunningham a combination compression-absorption plant.

Now and again comes as providential an oil development as that one of Skelly Oil Company at Cunningham. All the wells thus far producing in this field are Skelly wells. The wells are produced according to the latest principles of production engineering. The field is produced as a unit, with that degree of back-pressure as will yield the allowable production with the lowest gas-oil ratio. The oil is transported through the Skelly pipe line facilities, the gas processed in its gasoline plant, and the residue gas sold to a gas transportation system.

Taking into account the high normal rock pressure of the gas- and oil-producing horizons, company engineers designed a plant for long-time operation as a well pressure absorption plant, and restricted pipe line sizes to take advantage of the high pressure while the large volumes were available. Compressors were installed to boost the stripped gas to permit its delivery into the transportation company's facilities. This "situation" is another example of the natural gasoline plants' classic role as a conservator of a natural resource primarily produced concomitantly with oil. The gas has in the fullest sense served its energy function in the production of crude oil, and then is salvaged for its residual value as gasoline and gas.

Important Source of Motor Fuel

The most interesting developments regarding natural gasoline this past year have been not in processes nor in the construction of new plants, but, rather, in its use and its recognition as a definite or first source of motor fuel production. These two factors are likely to have a great influence upon the future price structure of natural gasoline in relation to motor fuel.

It might safely be said that never before was natural gasoline as widely used as last fall and winter to "pep up" refinery motor fuel. No other characteristic of motor fuel was ever more advertised than "quick starting." No characteristic ever caught the imagination of the motorist as did "quick starting." It was something every car driver could "feel" on a cold morning. The full-page advertisements in literally thousands of towns and cities made salesmen and the public "quick starting" conscious. Gasoline with 10 per cent points[3] of 110 deg. fahr., in extreme cases in the northern tier of states, and 115-120 deg. fahr.[4] north of the Mason-Dixon line, were not uncommon among the products of leading independent refiners.

There was simply not enough natural gasoline to go around, and, as a consequence, the price went well beyond a figure that represents a proper relation to motor fuel, as is shown by the following table. These prices were bound to be temporary and unstable. They began to drop steadily before the end of December, and by March were almost at the vanishing point.

[3]Recovered.

[4]With 50 per cent points at 200-220.

COMPARATIVE RATES 1933 MOTOR FUEL GROUP III (Below 59 Octane) and Natural Gasoline (26-70)

Month	*U. S. Motor*	*26-70 Natural*
January	2.45	2.15
February	2.25	2.0469
March	2.2187	1.7031
April	2.1094	1.2812
May	2.1625	1.2125
June	3.125	1.9844
July	3.7625	3.000
August	3.3906	3.0625
September	4.4531	4.500
October	4.225	5.1875
November	4.1719	5.0469
December	4.0937	3.9375

This coming fall and winter season will hardly, without question, witness a repetition of this unhealthy situation. It has ever been thus, a feast or famine. Two remedies have been suggested, additional storage, and more or less compulsory use of natural gasoline by all refiners as a part of their motor fuel allocation.

Allocate Naturals to Refiners

As has been already said, it is being gradually almost universally recognized that all natural gasoline heretofore or now being produced was and is absorbed continuously. No more, no less crude will have to be produced, or processed in refineries. This gasoline[5] is the first gasoline produced from crude oil, even before the crude itself leaves the lease. For this reason, and because it is produced of necessity along with crude oil, its production cannot conomically be curtailed except as crude production is itself curtailed. Furthermore, since, because of the practical absence of storage, it is literally daily marketed, all that is needed to eliminate its chaotic marketing is to control its flow to the markets. It is planned to effectuate this control by taking all the natural gasoline production into account in the allowable motor fuel production for the country, and so to allocate to individual refiners as will of necessity force them to use a certain percentage of natural gasoline at all times or forego the privilege of producing a like amount of gasoline from crude.

This novel scheme has a great deal to merit its trial. While there will be a great deal of objection on the part of refiners who are so located that they cannot use their allocated share of natural gasoline, because of climatic conditions or high freight rates, these objections should not be allowed to prevent at least a fair trial of a plan to which informed men have given a great deal of study. Inequalities and hardships can be ironed out as experience dictates. Meanwhile, the depressing effect of naturals upon the prices of all classes of motor fuels justifies the hope of natural gasoline manufacturers that the recently evolved plan for the utilization of natural gasoline will, with whatever modifications may be necessary, be given a fair trial.

This writer believes that a great deal of progress has been made in "finding a market" for natural gasoline in the past twelve months. The general recognition of the place occupied by natural gasoline in the overall national motor fuel picture, and its increasing popularity as an important constituent of winter motor fuel, justify a reasonable hope that natural gasoline will come into its own. It may be truly said that at this very hour natural gasoline is emerging as the fifth[6] major branch of the oil industry and that in future councils it will play an important part in the deliberations affecting the destiny of the oil industry.

[5]Except the few per cent produced from natural gas.

[6]Production, refining, transportation, marketing.

Treatment of Creek Water For Compressor Station Use

By F. B. TAYLOR, JR.
Panhandle Eastern Pipe Line Co.

A Controlled Water-Treating System of High Efficiency

AN UNUSUALLY low cost method of treating creek water for scale-forming impurities is now being employed by the Panhandle Eastern Pipe Line Company at their compressor station near Paola, Kansas. Sufficient water to supply the jackets of three 185-hp. engines and direct-connected compressors, or approximately 18,000 gallons, is treated daily by an intermittent process at a cost of 5.2 cents per 1000 gallons. The proportions of the softening agents used are determined from daily tests made at the plant by the station superintendent. These tests, and other necessary attention to the treatment, require not more than 30 minutes each day. The method has been in service more than a year and has given entirely satisfactory results.

The small creek from which the water is pumped is sluggish, so there is considerable stagnation, resulting in a slightly high percentage of soil acids from plant decay. A considerable quantity of fine silt also is held in suspension in the stream; and due to evaporation in the summer months, the impurities are somewhat concentrated.

Water analyses, although similar, will vary in different localities where the water shed is geologically early or late; particularly in lakes where prolonged contact with certain formations results in concentrations of various impurities. In this particular case, besides the soil acids already mentioned, other acids, the products of decay, were found to be present, as well as the more common hardening compounds: calcium carbonate, magnesium carbonate, silica, magnesium chloride and calcium sulphate. Mud, or minute suspended matter, was present in appreciable amounts. These conditions parallel those found generally throughout the Mississippi Basin, so far as surface water is concerned.

As an economical installation of equipment was of primary importance it was decided to attempt an intermittent treatment of the water in tanks, rather than install heaters, filtration equipment, or a zeolitic system. For this purpose two 3600-gal. steel storage tanks were set up a short distance from each other in the manner shown in Fig. 1.

Midway between the tanks a 3-in. riser, with an overhead swing to the manhole of each tank, was erected for charging the tanks with raw water from the creek. A 3-in. nipple was welded into the bottom center of each tank to serve as a drain line for the sedimentary material. A ladder was placed between the tanks, with a short catwalk across the tops.

The outlet for the treated water is through a 4-in. line rising 15 in. above the bottom. This space of 15 in. is important in that it allows plenty of space at the bottom of the tanks for the collection of precipitation resulting from the reactions. In draining out this waste material it was found advisable to leave from 3 to 4 in. of the sludge in the bottom of each tank. The reason for this practice will be shown later.

The actual problems confronted in softening the water sufficiently for the desired purpose were not out of the ordinary. The use to which water is to be put usually determines the extent of the treatment, boiler water being brought to zero, or near-zero, hardness. Jacket water is seldom treated so thoroughly; but in this case operating conditions demanded an almost soft water.

Scale-forming solids, and mud, were to be removed from the water. Treatment also was necessary to neutralize corrosive acids such as the previously mentioned soil acids, and

TABLE 1

This table calculated to the total hardness in grains per U. S. gallon when a 50-cc. sample is tested. When the sample requires more than 7.9 cc. of soap solution a 25-cc. sample should be tested, doubling the results shown in the table.

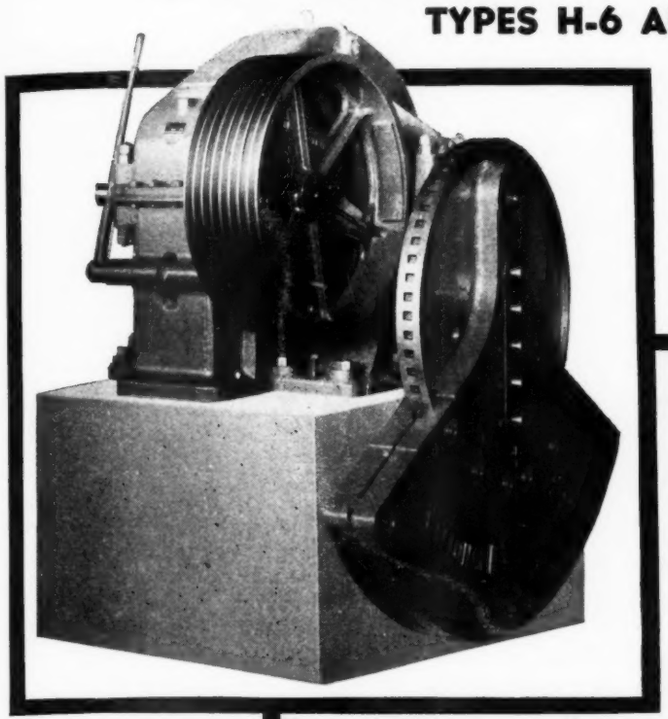
cc.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	.....	.....	.....	.....	.....	.....	.....	.....	.06	.18
1	.28	.37	.46	.55	.65	.74	.83	.91	.99	1.06
2	1.14	1.21	1.29	1.37	1.44	1.51	1.59	1.67	1.74	1.82
3	1.90	1.97	2.04	2.12	2.20	2.27	2.35	2.42	2.50	2.58
4	2.66	2.74	2.83	2.91	2.99	3.07	3.15	3.23	3.32	3.42
5	3.50	3.57	3.65	3.72	3.80	3.87	3.95	4.02	4.12	4.25
6	4.33	4.41	4.49	4.57	4.65	4.73	4.81	4.89	4.97	5.04
7	5.16	5.25	5.33	5.41	5.49	5.57	5.65	5.74	5.83	5.92

MATERIALS REQUIRED

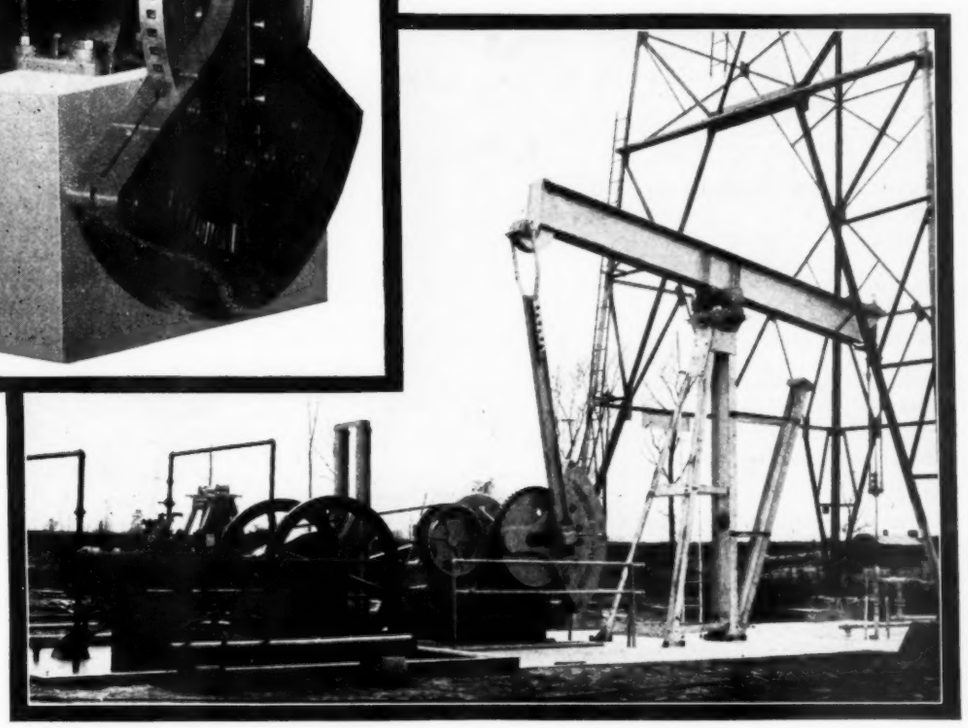
A.P.H.A. Soap Solution:

1 25-cc. burette
2 300-cc. Erlenmeyer flasks
2 No. 5 rubber stoppers
1 ring stand support
1 burette clamp
1 50-cc. graduate

NATIONAL
PUMPING UNITS
TYPES H-6 AND H-7



An East Texas installation of the H-6 Pumping Unit with National Type H Belt Tightener and with Superior 40 H. P. Gas Engine.



Bulletin No. 534-A free on request.

The National Type H-6 and H-7 Pumping Units are sturdy reduction gears for operating walking beams. Designed and constructed for supporting heavy rod line loads, which are balanced over an unusual range of conditions, these Units will operate indefinitely at their rated capacities efficiently and economically.

THE NATIONAL SUPPLY COMPANY

to remove salts, as magnesium chloride, that otherwise ionize to form acids.

After considerable experimentation a treatment was developed, using lime (CaO), sodium aluminate ($Na_2A1_2O_4$) and soda ash (Na_2Co_3) as the reagents. Although no new chemical reactions are involved a very high efficiency has been obtained without the necessity of preheating the water to be treated. This latter is a factor important in safety consideration at a gas compressor station. Likewise, the treating chemicals are readily handled and not of such bulk as to require much storage space.

Two typical equations, precipitating the $CaCo_3$ and $Mg(OH)_2$ but leaving in solution $Ca(OH)_2$, due to the excess of lime used, are given below.

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2CaCO_3 \downarrow + Mg(OH)_2 + 2H_2O$$

However, the excess of lime used forms the hydroxide, $Ca(OH)_2$, which is hardness-forming in itself, and which remains in the solution. This is removed with sodium carbonate according to the following reaction:

$$Ca(OH)_2 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + 2NaOH.$$

The sodium carbonate, or soda ash also reacts with calcium sulphate ($CaSO_4$) as:

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 \downarrow + Na_2SO_4$$

Thus completing the softening reactions.

Carbon dioxide, CO_2, frequently found dissolved in water forms carbonic acid, or H_2CO_3, which accelerates corrosion of iron castings. This detrimental effect is neutralized by the following reaction:

$$Ca(OH)_2 + H_2O + CO_2 \longrightarrow CaCO_3 \downarrow + 2H_2O$$

Silica, the major constituent of silt, remains unchanged in the solution. However, the sodium aluminate, used as coagulant, tends to remove a considerable amount of this impurity simply by its coagulating action.

These reactions, occurring in the treating tanks, produce a dispersion of the molecular particles resulting from the interchange of the chemical radicals. However, as the specific gravity of the particles is not great, they remain in suspension. This turbidity would remain for hours were not some means employed for dropping the precipitate to the bottom of the tanks. Sodium aluminate is employed for this purpose, as indicated above.

With water, sodium aluminate produces a thin jelly which, in sinking to the bottom, collects and carries the suspended matter along. This settling action is greatly aided by the three or four inches of sludge mentioned as being left in the tank bottom. This sludge contains a slight excess of the treating reagents, including the jelly-like material due to the reaction of sodium aluminate and water. When agitated it is dispersed throughout the mix and hastens the precipitation. In this manner the amount of sodium aluminate necessary to the reaction is decreased considerably, effecting a worthwhile saving.

From Fig. 1 it will be seen that the water to be treated is discharged into the tanks through perforated buckets suspended from the manholes. It is in these buckets, rather than in the tanks themselves, that the softening reagents are placed. In this way a thorough solution of the chemicals is obtained.

Practice developed an important fact relative to adding the reagents. It was determined that a chemical reaction occurred if the three treating compounds were mixed externally and then dumped into the tanks. To overcome this disadvantage the reagents are now added in the following order: first, lime; second, sodium aluminate, and last, soda ash. After they have been carried into the water the mix is agitated by air through an 8-ft. length of ⅜-in. pipe connected by means of rubber tubing to the station air supply. Pumping, treating and settling requires from eight to nine hours. The treated water is directed into the hotwell and thence into the cooling system.

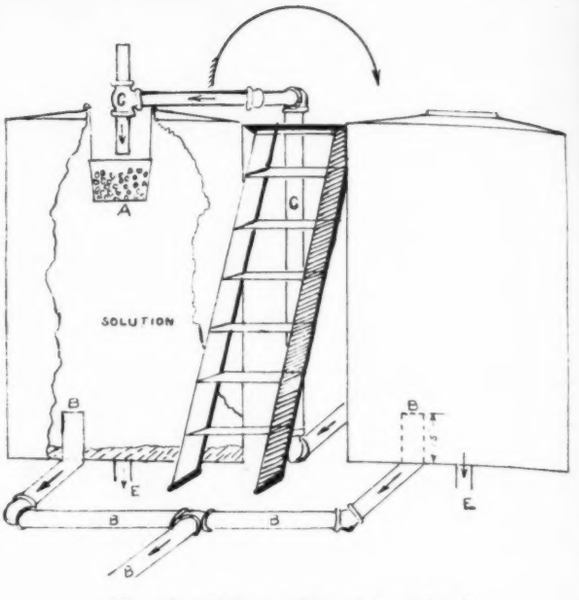


Fig. 1—Water-Treating Tanks

- **A. Perforated Charging Bucket**
- **B. Treated Water Outlet to Hotwell**
- **C. Raw Water From Creek**
- **D. Sludge Outlets**

The treated water is tested by the A.P.H.A. method for causticity and alkalinity, and the proportions of the reagents varied to meet changing conditions. A slight excess of each compound is used to insure near-zero hardness. An average charge for one tank equals seven pounds of lime, one pound of aluminate and three pounds of soda ash. The water is tested by the A.P.H.A. soap method for hardness to determine the overall preformance of the treatment. (See Table 1).

Present fluctuating market prices of soda ash, aluminate and lime make the treatment of 1000 gallons of water average 5.2 cents; however, in the winter months, the minimum cost was 4.3 cents, and in the summer a maximum cost (due to the concentration of impurities by evaporation) was 5.9 cents. The time required of the station engineers for the treating and testing of the water is not calculated in the above figures, nor are power incidentals.

This method of treatment results in a 43 to 80 per cent saving over other compounded treatments and as high as 200 per cent in the case of a certain compounded treatment. Low equipment cost is an added advantage.

Frequent inspections of the cooling jackets of the three units in service at the station have proved the effectiveness of the treatment. No scale has been formed. The three units are rated at 185 hp. and have been operated 98.4 per cent of the time during the past year.

Such continuous operation requires thorough water treatment and the process employed was found entirely satisfactory from both the practical and economical standpoints.

A Neglected Hazard

By J. F. CORCORAN*

FOR a number of years a great deal of time has been given to and a vast amount of money spent in study and research pertaining to safety methods in industry. Engineers have made a study of the subject, volumes have been written about it. Almost every company, manufacturer, producer, refiner and others who employ labor has a safety department head or committee concerned with the study of the various hazards connected with its own line of work.

If one could follow through with one of these safety groups, it would seem they have left nothing undone to protect the life and limb of their employees, but in almost every group one hazard seems to be neglected. Railings are erected around moving parts, belts and pulleys are protected with guards; elevator wells are equipped with automatic gates, signs of warning of every description are put up, such as, "Be Careful," "Watch Your Step." "Beware of Cars," "Safety First," and many other such warnings, and yet the hazard I have in mind is generally overlooked. The neglected hazard I have in mind is unsafe and worn-out hand tools.

Safety inspectors make their rounds of inspection, old railings are replaced, old floors are renewed and other general repairs are made to guard against the slightest accident, and they again fail to report this apparently unseen or neglected hazard.

Cases In Point

Unsafe and worn hand tools are without doubt a very great hazard to those using them, as the average mechanic or workman relies almost too much on the strength and sureness of the tool he is using. Let me illustrate this with a few actual experiences. I watched two men take a 36-in. pipe wrench on top of a tank car to do some work. They put all their strength on this tool; the handle broke and both men fell from the car, one breaking his arm. I inspected the wrench, and the foreman who allowed these men to use such an old worn-out tool should be reprimanded.

Another case: I was making a strength test in a machine shop and asked for a heavy hammer. I was given one with a loose head so I asked for a better one. The shopman said that was the best he had. "I will show you," he said, "how to use it." As he was striking the second blow the head flew off and struck a steam gauge being repaired and smashed it. No one was hurt but a costly gauge was almost demolished.

One more case: I was standing in an oil field, waiting to talk with the foreman of a gang. He was making an emergency repair on a feed line that had broken. I had a couple of 24-in. pipe wrenches in my hand, and was watching two men hurry to make the repairs. They were having a great deal of difficulty as the wrenches they were using would not hold; one of the men asked me to loan him my wrenches, and an hour later he returned them and said in language more forceful than elegant, "I wish this blankety blank outfit would buy us some decent tools," etc.

* Trimont Manufacturing Company

Loss of Life and Money

I could write of many instances where unsafe hand tools have cost money to companies and have caused painful and often fatal injury. The cost in this respect is tremendous. In one state alone, for example, for only one year, there were five deaths, 7,389 serious accidents costing $1,574,455. Consider just for a minute how many new tools this amount of money would have purchased and the number of accidents with their serious consequences that could have been avoided.

How are we to get away from this hazard? The answer is simple. Make a weekly inspection of your tool room, discard or repair any tool unfit for use. Don't allow your tool room man to give out any tools unfit for use. Penalize the workman you find using a dangerous tool.

Use the same care in inspecting your tool room equipment as you do in inspecting any other piece of equipment. Don't expect your workmen to erect safety devices, using unsafe tools. Your effort to avoid accidents is handicapped before you start.

Being interested in safe tools, I inspected the tool house of a large company with one of their men, and we counted over 50 pipe wrenches unfit for service.

Discard Unsafe Tools

Make an inspection of your tool equipment now, and the result will amaze you. You will wonder how so few accidents occur with such poor tools. Don't hesitate to discard unsafe tools — a few dollars will replace your entire hand tool equipment, whereas one accident causing severe injury cannot be paid for.

Do not allow your tool equipment to become so old and worn out that it will cost you life or limb before you replace it.

A Good Practice

Apparently the importance of this neglected hazard is beginning to be realized as I understand one of the major oil companies in the Mid-Continent fields has appointed a committee of two to look into the hand tool situation in its organization as regards safety and quality. As I see it, if this same practice were followed by other companies they could, without question, cut maintenance cost and take most of the risk out of dangerous tool work.

A Complete LINE of "PROVED-IN-SERVICE" OIL FIELD EQUIPMENT

Take the time to LOOK IT OVER When the IDECO man calls!

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Crown Blocks
Derricks
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Jack Posts—(Steel)
Rig Irons
Samson Posts—(Steel)
Sand Reels
Stems
Jack Shafts
Tubing Blocks
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Fish Tail Bits
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Elevators
Fishing Tools
Gas Engines
Temper Screws
Gas Trap Supports
Geared Speed Reducers
Polished Rod Grips

THESE are days when management is "overlooking no bets" to pare down waste and overhead! Can costs be cut? Can production be stepped up? Is obsolete or worn-out equipment penalizing profits? These are questions every oil company executive is vitally concerned with today.

In the big book above are sound answers to some of these problems. It is the complete IDECO catalog, illustrating and describing in detail the wealth of equipment developed by IDECO engineers for making field operations more efficient and less costly.

When the IDECO man calls on you, take the time to look this book over and see what a complete service IDECO offers you. Or if you want specific information mailed you on any piece of IDECO equipment listed at the left, please write

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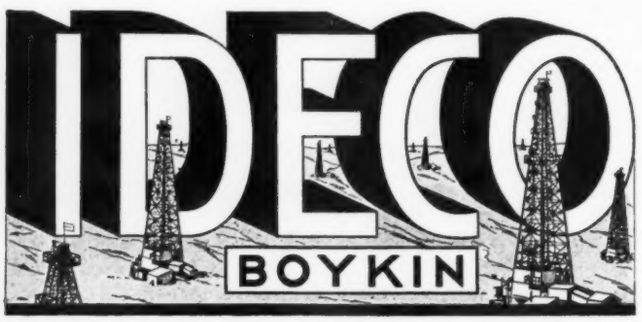


Long String of Tubing Pulled with Portable Equipment

The crew of Group No. 1 Oil Corporation, Rita Santa, Texas, shown below, is pulling the original No. 1-B well on the University's lease in the Big Lake oil field. Until recently this was the world's deepest producing well. Since its discovery, lending impetus to deeper drilling, a complete change in both drilling and producing equipment has been wrought, calling for much larger capacity machinery than ever before manufactured.

The well again made history on April 13, when tubing was pulled, it being the longest string ever pulled with portable equipment. The total depth of the well is 8671 feet.

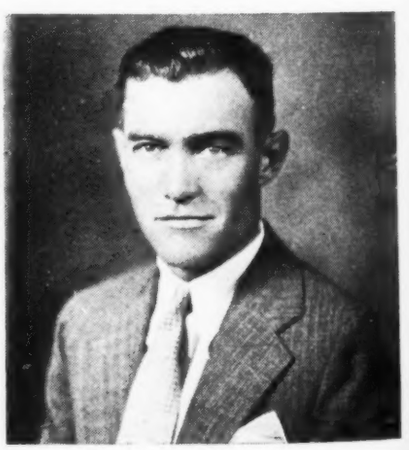
The new Allis-Chalmers Rumely "U-6" Skid Winch, which was just delivered to the Group No. 1 Oil Corporation, is built especially for deep wells, and pulled with ease the 8394 ft. of special, heavy, 2½-in. upset tubing. It pulled the first three joints in low gear, the fourth joint in second gear and the fifth joint in third gear.

The men in the picture are R. W. Gough, O. L. Fisher, G. F. ("Slick") Duncan, W. W. Hunt, E. W. Sweeden, J. E. Hutchins, J. A. Wikon and Mark Wilkinson. J. E. Warren, district superintendent, does not appear in the picture.

Southern States Company, Inc., Moves Headquarters to Dallas

The Southern States Co., Inc., on June 1 moved general headquarters from Shreveport, La., to Dallas, Tex., 1113 Tower Petroleum Building. The announcement was made by H. C. Otis.

J. C. ("Red") Luccous is being transferred from Oklahoma City, Okla., to Houston, Texas, and will be the Gulf Coast representative of the firm.



H. C. OTIS

The Southern States Company, Inc., specializes in tubing high-pressure wells, manufacturing and servicing Otis removable bottom hole chokes, and other products, including mixing and bottom hole valves.

NEW

GUIBERSON TUBING SPIDERS

•••

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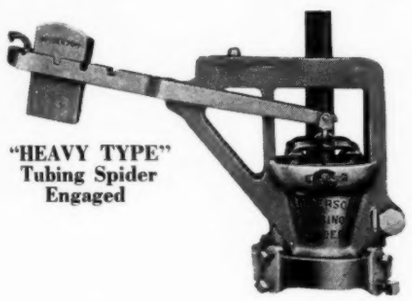

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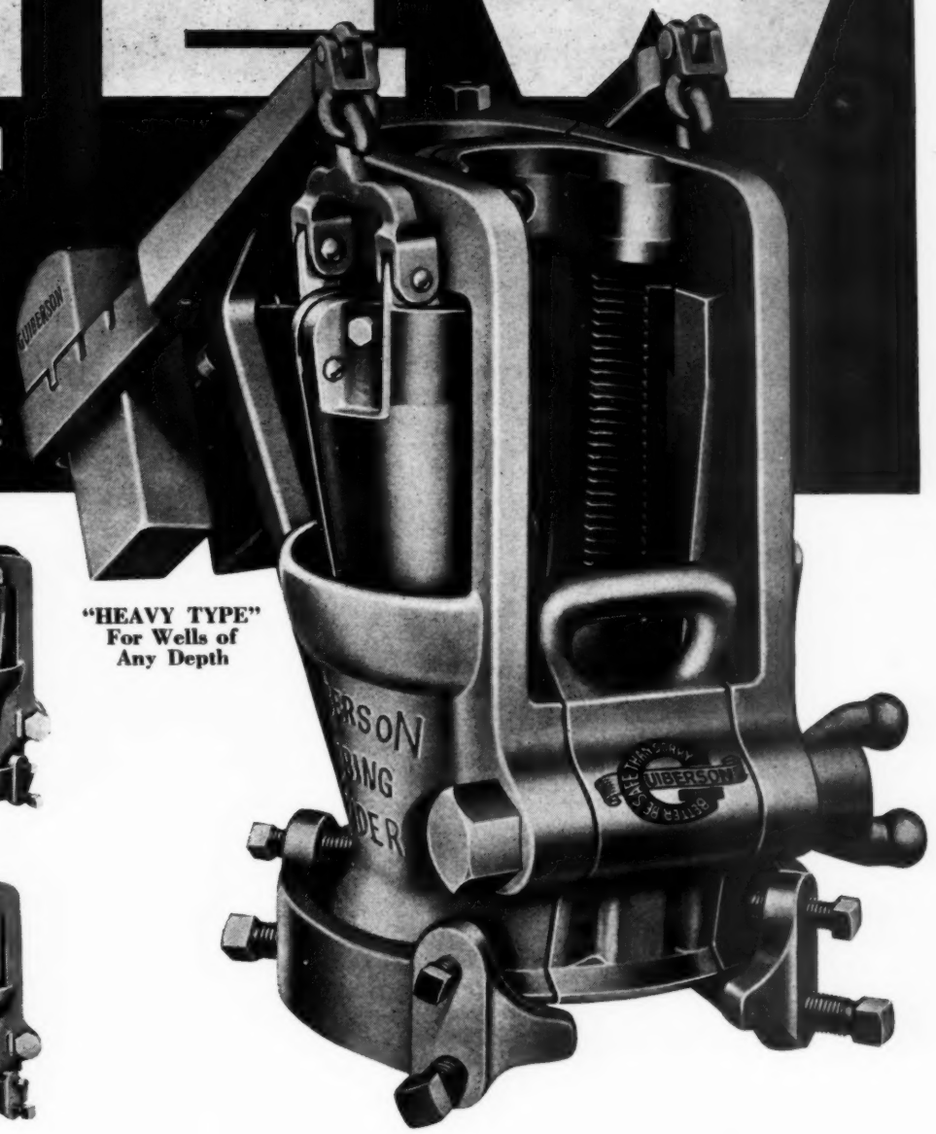

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BETTER BE SAFE THAN SORRY

A Review of Progress in Protecting Pipe Lines

By STARR THAYER
Electrolysis Engineer
United Gas System

NO official of a company operating pipe line systems is too busy or too big to neglect the subject of pipe corrosion. Not that he should necessarily understand the subject but he should see that his company has the proper personnel to combat this troublesome problem.

The corrision engineer should not merely be a man who goes out onto the line once in a while and sees that some black paint is put on the pipe. It should be possible for him to keep in touch with fellow engineers and to obtain the results of the organizations and bureaus organized for the purpose of combating corrosion.

It is becoming more and more apparent that the corrosion engineer and those interested in this work must keep studying continually if he is to reap the full benefits of all available information. No doubt, more progress has been made within the past three or four years in solving these problems than in all the previous years combined.

For years but little attention was given to this work. What progress was made was the results of work by a few scattered individuals. Many of them were probably at times working on some particular problem that others already knew the answers to.

With the advent of steel pipe lines for oil and natural gas came a host of manufactured coatings. It was soon learned that most of the coatings offered were of little value. As the miles of pipe lines continued to grow it became apparent that something must be done to solve this problem.

This led to the organization of sections of the A.P.I. and A.G.A. and a section of the Bureau of Standards. Scientists were employed to devote their full time to the work. Valuable data soon became available by using the information already developed by the individuals and by further research.

By studying the reports of these organizations and attending the yearly meetings if possible, one can obtain much valuable information as to what the industry as a whole is doing. Surely one will waste much time and possibly money in lost pipe lines if he undertakes to start from scratch and work the problems out himself.

New Pipe Lines

In the construction of a new line two problems are immediately presented. First, will it be necessary to combat corrosion; and second, if so, with what method?

Machine for applying a hot coating to pipe in the field

Soil Surveys

To the experienced corrosion engineer the first problem is now becoming easier. Much of the guess work as to the corrosive qualities has been eliminated. It is to be hoped that still more accurate and rapid methods will be devised to solve this feature of the work.

Pipe Coatings

If a protection must be afforded against corrosion many questions must be answered. There seems to be nothing at present to indicate that there ever will be a practical non-corrosive pipe metal; therefore, a coating material is necessary.

Roughly, the different types of coatings can be divided into three classes: Portland Cement, Grease, and Bitumin. The Bitumins can be divided into hot and cold applications and again into asphalt and coal tar pitch bases.

With the possible exception of the Portland Cement, practically all of the information needed can be had on any of these types.

From the data accumulated recently and by using common sense it is comparatively easy to specify what a pipe coating should be. There are in all only about seven fundamental characteristics that a coating material must have:

1. It must adhere to the pipe.
2. It must resist soil stress.
3. It must resist moisture penetration.
4. It must be of high electrical resistance.
5. These qualities must be permanent.
6. It must be practical to apply.
7. Its cost must be within reason.

Wrappers

Much worth-while information on wrappers is now available.

The behavior of the different types of material and their prospective life is fairly accurately known. A question in regard to wrappers that still seems to be a debated point is whether the wrapper should be bonded or not. The advocates of the loose or unbonded wrapper seem to have the better of the debate at present.

Cleaning Machines

More progress has been made recently in obtaining a good coating application than possibly in any other single phase of the work.

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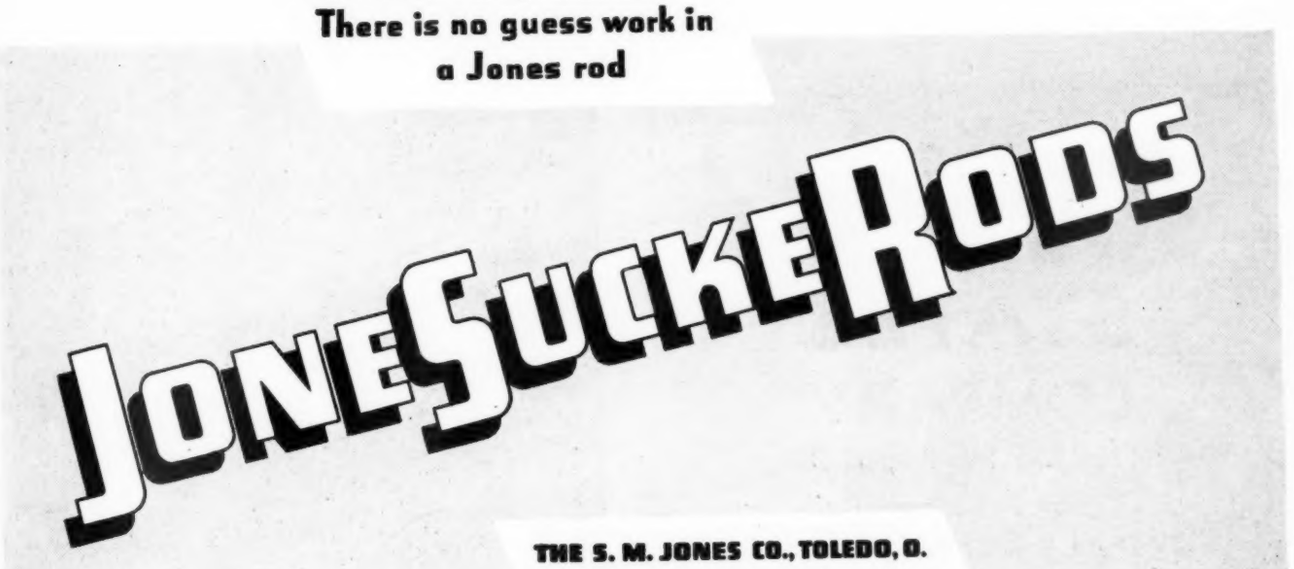

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Sling method of applying hot coating, with metal pans carried beneath and back of sling to eliminate waste

Pipe cleaning machines to prepare the pipe surface, whether new or old pipe, are being constantly improved. No doubt more improvements will be made in the future.

Coating Machines

The application of a hot coating in the field by machine is now possible and practical in many cases. It is not known this machine will operate, using the coal tar pitches of higher melting point. Mechanical defects in the machine, if any at present, should be easily overcome.

Electric holiday detector

One company using the old sling method of application has devised light-weight metal pans to be carried along back of the sling. This has been found very much worth while, as it almost completely eliminates waste. It also produces a much better job as the enamel can be flooded on in large quantities with the knowledge that there will be no waste.

Holiday Detector

Until recently the only way of determining the amount of holidays left in the coating was by visual inspection. We know now that this was very unsatisfactory.

A simple and inexpensive electrical detector is now to be had. This detector consists primarily in a loop around the pipe to which bristles are attached. The loop is attached to one terminal of a high voltage coil and the bare pipe to the other terminal. When a holiday is passed by the bristles a spark will occur which can be seen and heard. Also hidden bubbles in the coating will be exposed. This devise will find holidays that are almost invisible to the eye.

A practical demonstration was recently made of this device. One hundred feet of 12-in. pipe was coated; it was then inspected for holidays by four inexperienced inspectors. All holidays were repaired and the electrical detector was then used. An additional 48 holidays were then found.

Perhaps the one single improvement noticed on modern construction jobs that stands out above all others is the attitude of the workmen. Where it is apparent that the owners appreciate the value of the protective coating and are using every available means to obtain a perfect application it is remarkable to see the class of work turned out as compared to the old slip-shod, careless jobs. The careless or indifferent workman will not last long in a modern coating crew.

Electrical Protection

It often now is possible to save a reconditioning job by the use of direct current applied to the line.

This subject has been much discused recently and many papers are available on the subject.

This method consists primarily in applying the negative terminal of a direct current to the pipe line. The positive terminal is connected to a ground bed consisting of cast-iron or scrap steel pipes. The current is then forced off the ground bed, into the soil and onto the pipe line at the abrasions in the old coating.

It is obvious that this amount of current required will be in proportion to the resistance of the coating and to a lesser degree to the number of holidays in the coating. It has not been found practical to so protect a bare pipe line. The low resistance coatings make the cost for purchased power very high.

Conclusion

Much progress has been made within the past year and it is to be hoped that more will be made the coming year.

The economics of properly protecting pipes are apparent. One simple example will illustrate. We will suppose that it costs $1,000.00 to coat a mile of pipe—to recondition this mile will cost approximately $5,000.00. If the line bare will serve for five years we have gained the interest on the investment of $1,000.00 for that period. However, we now have the $5,000.00 expenditure to meet.

Knowing what we do now, it should be possible to locate the perspective "hot spots" and select a coating that will protect the pipe. Reconditioning of pipe lines should become a thing of the past as soon as the present cycle has been worked out.

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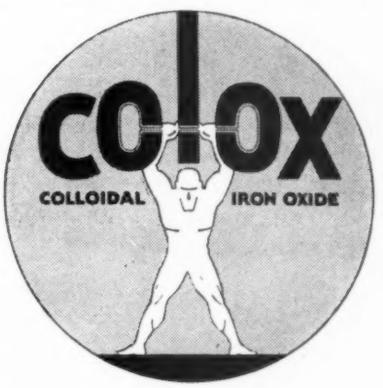

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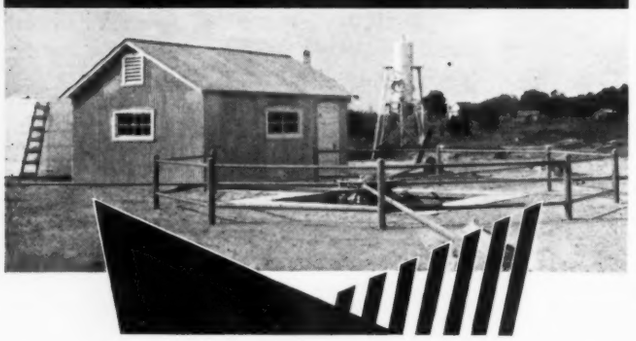

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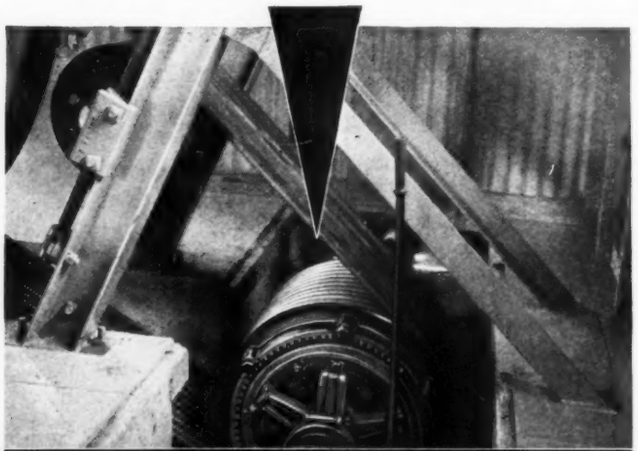

TWIN DISC CLUTCHES

D-B Celebrates Safety Record

The D-B Division of the Emsco Derrick and Equipment Company, Los Angeles, California, on May 15th celebrated its third consecutive year of no lost time accidents, a record of which the company feels justly proud. In the afternoon all the officials and employees gathered at the plant to enjoy refreshments and a varied selection of entertainment.

The D-B Division of Emsco Derrick and Equipment Company is the manufacturing unit where all D-B Pumps, pump parts, sucker rods, etc., are fabricated and is under the direct supervision of E. E. Stevenson.

While business was not a part of the festivities, informal talks were made by J. S. A. Smith, secretary and treasurer; E. E. Stevenson, chief engineer; P. F. Steinmetz, advertising manager; O. Krawitz, chairman of the safety committee; Mr. Fittus of the Travelers Insurance Company and others of the Emsco and D-B personnel.

The meeting was inspirational in that each member of the company feels a keen desire to continue this successful safety record over a much longer period, and such meetings with this specific purpose in view undoubtedly will result in great strides in that direction.

Chain Belt Company Reopens Houston Office

The Chain Belt Company, Milwaukee, Wisconsin, announces the re-opening of its office in Houston, Texas, in charge of J. W. Snavely. The office is located at 3118 Harrisburg Boulevard and mail should be sent to Postoffice Box 1812.

Mr. Snavely graduated from the University of Wisconsin and entered the employ of the Chain Belt Company as a student apprentice in 1927. The next three years he spent in the factory receiving training in the various manufacturing departments. In 1930 he received additional experience in Oklahoma City and surrounding oil fields and then spent a considerable time in East Texas. Since then Mr. Snavely has been doing sales work at the home office in Milwaukee, and has specialized in the development and promotion of REX Deepwell Oil Chains.

The Chain Belt Company, besides manufacturing chains for the oil field and for every industrial field, also makes a complete line of construction equipment, sanitation equipment, transmission equipment, castings, conveying and material handling equipment.

New Oil Well Survey Office Opened in Long Beach, California

Alexander Anderson, Inc., of Fullerton, California, has opened a branch office at the corner of Willow and Pasadena Avenues in Long Beach, California, to provide continuous day and night underground survey service in that district. The additional service thus provided has been made necessary by increased demand for the measurement of both inclination and direction in drilling wells, Mr. Anderson announces.

While all six of the Anderson survey instruments are available at the Long Beach office, special attention is being given to operating the new Photo-Record Single Shot and the Standard Orienting Survey. The former gives the inclination and angle of a well at any point in open hole whenever the information is desired. It is run either by the operator himself or by the Anderson organization. The oriented survey is the complete survey of a well, giving the inclination and direction throughout its entire depth.

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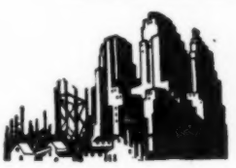

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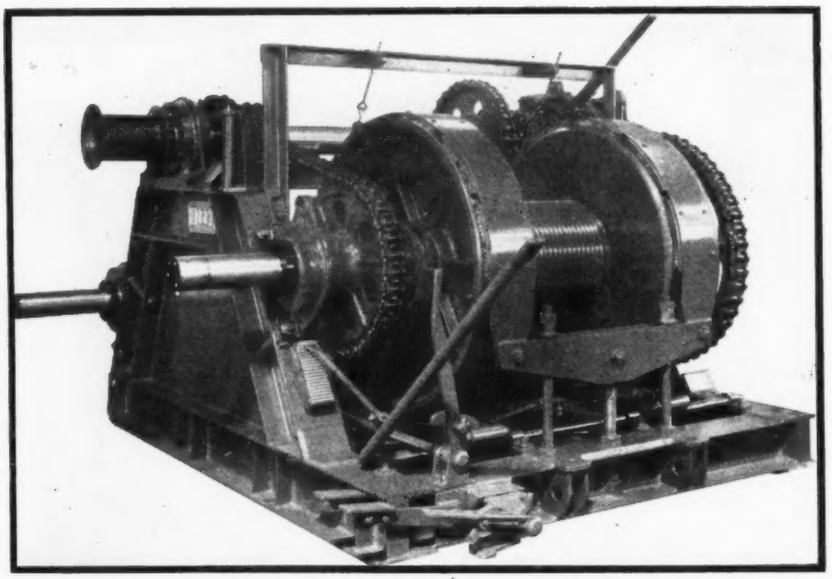
Progress and Trends in Drilling Practice



The modern trend toward portability in drilling equipment is seen in this compact unit for deep drilling, which has the capacity of a conventional drawworks.

By K. C. SCLATER

DRILLING and wildcatting have at last emerged from a period of comparative inactivity. A year ago, drilling on the whole was at a low ebb. Today, drilling activity is greater than it has been for several years. The revived activity has stimulated interest in improved methods and presents an excellent opportunity to observe the progress and trends in drilling practice.

Many notable improvements and innovations in drilling methods and equipment mark this revival of drilling operations and these cover every phase of this important branch of oil field exploitation. Probably foremost among the innovations is controlled directional drilling, widespread attention to which was attracted by the controlled whipstocking methods used with such conspicuous success in the Conroe field to drill an inclined relief well that resulted in the eventual killing of the cratered well in that field.

Pressure drilling methods are in wider use and have been improved by equipment of modern design.

The increasing necessity for wildcatting in isolated areas has led to the adoption of prime movers other than steam engines. Diesel mechanical and gas-electric power drives are in use on deep wells. Interesting data obtained point to the feasibility and flexibility of prime movers of this type for drilling.

In the Belridge field, California, at this writing, a well is being drilled at a depth greater than 1100 ft. and draws attention not only to the improved methods of handling drill pipe, but also to the improvement in design and materials. Flush-joint drill pipe has been adopted for use in the Gulf Coast for drilling through heaving shale and in areas where unconsolidated high-pressure gas sands create a serious blowout hazard.

Mud fluids are being studied to ascertain the part they play in blowouts in the Gulf Coast. Field tests made to determine the changes in pressure on withdrawal of the drill pipe from the hole indicate that proper conditioning of the mud will go far toward reducing blowouts.

Advanced practice in cementing deep wells by multi-stage cementing has been successful in reducing the difficulties of setting casing in deep holes. An interesting development in California is the setting of liners in sections and successfully cementing off barren strata between productive horizons in a well.

Progress in coring is evident in the increasing use of electrical coring and correlation, the wire-line coring bit, and the application of the core bit in cable-tool coring.

In the fields of the Texas and Louisiana Gulf Coast the setting of derrick and complete drilling equipment on barges for drilling shallow wells located in deep water has given a high degree of portability, has speeded up drilling and reduced development costs.

Auxiliary aids to drilling have recently appeared. One of these is an instrument by means of which the driller can maintain closer control of the performance of the bit and obtain greater footage than when he depends solely on his own intuition and experience.

Controlled Directional Drilling

Controlled directional drilling, the successful development work on which had been done in California by H. John Eastman, came into the limelight when it was employed with such remarkable skill in the Conroe field, Texas, to kill a cratered well that had resisted all efforts to bring it under control. Aside from the highly successful and novel application in this instance, controlled directional drilling opens up enormous possibilities that are even now almost too vast to contemplate. Not the least among these possibilities is the drilling of two or more holes from one well location at the surface. Instead of depending on one vertical hole for production, two or more holes drilled at a more advantageous angle of inclination for more effective drainage are possible. This is an item of far-reaching importance that must be considered in the problem of well-spacing. It cannot be neglected, for eventually it will have a vital bearing on the subsurface engineering phases of oil field development. New problems of depletion are bound to arise that ultimately may have a far-reaching influence on future oil field practice.

Drilling of the relief well was undertaken by the Humble

Oil and Refining Company in order to kill the cratered well, Harrison and Abercrombie's No. 1 Alexander, in the Conroe field. A location was made for the relief well 412 ft. distant from the cratered well. Drilling began November 13, 1933, and on January 9, 1934, the cratered well was killed. A vertical hole was drilled to 1960 ft. and from this point on an inclined hole was drilled under the direct supervision of Eastman. Special whipstocking tools were used to begin the inclined hole. Careful surveys of the hole and close control of drilling bit action and rotating speeds were brought into play and a hole with the required drift successfully drilled to a depth of 5135 feet. As each 100 ft. of hole was drilled it was surveyed by an Eastman instrument, and the readings checked with those of two other instruments. After each set of readings, determinations were made of the amount of drift required and drilling controlled accordingly for another 100 feet. At the final check-up the calculated total amount of drift at a depth of 5015 ft. was 411 ft. in an almost southwesterly direction, and coincided almost exactly with course mapped for the hole, the bottom of which was at 5135 feet.

In this instance, the formations offered no particular difficulty in drilling an inclined hole. On the other hand, considering the hazards involved and the drastic nature of the precautionary measures it was necessary to observe, the accurate drift of the hole obtained and the successful outcome of the whole undertaking constituted a daring and superb piece of oil field engineering. The drilling of this inclined hole has served to emphasize the practicability and the possibilities of controlled directional drilling.

As an economy measure to eliminate the cost of one foundation in a field where the well foundation is a costly item, two holes were drilled from one surface location. In the Elwood field, California, almost half of which is underneath the Pacific Ocean, the Barnsdall and Rio Grande Oil companies, having been granted tideland permits by the state, were entitled to exploit that part of the field lying beyond the mean high tide line on the ocean side. By drilling inclined holes, accurately controlled as to drift, two wells were drilled from a common foundation and having a common conductor casing. It is estimated that the foundation for a tideland well costs $40,000. An additional $10,000 to $15,000 must be allowed for a pier. For each extra hole thus drilled from a common foundation on a tideland permit, a considerable item of expense is eliminated. The average depth of these wells is 3500 ft. and the drift of the holes was closely controlled and kept within the limits of the permit.

Drilling of the wells was done through a 48-in. steel conductor casing 56 ft. long, which was landed on hard shale some depth below the ocean floor. The first hole was drilled off center in the conductor casing. A short string of 18⅝-in. casing, which was subsequently pulled, was then run as a guide string. At about 500 ft. a string of 13⅝-in. casing, extending to the surface, was set and cemented on bottom and, in addition, was tied into the bottom of the 48-in. conductor casing. Bit-deflecting devices were used to obtain the necessary inclination of the hole. The methods used in drilling these two wells are adaptable to the drilling of more than this number if necessary. It is estimated that a saving of $65,000 was made by drilling these two wells in this manner. The method also adapts itself to fields having several producing zones of great thickness. It is an interesting adaptation of controlled directional drilling.

Pressure Drilling

Completion of deep wells by means of pressure-drilling equipment has been brought to an advanced stage of development in the Big Lake field, West Texas, where it has been in continuous use for almost two years. When this

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method of completing wells was first used there it was with the object first, of keeping the well alive while drilling and preventing any injury to the pay sand by injection of drilling fluid, and second, of conserving the gas and the reservoir pressure.

Further improvements have been made during the past year in this phase of well completion. Its use has been extended to the drilling of wells in high-pressure gas areas in the Gulf Coast, where blowouts are a menace. Concurrent with improvements in pressure drilling is an increasing use of hydraulic feed equipment. According to Foran[1] eight wells in all had been completed under pressure control in the Big Lake field up to the beginning of April, 1934. These range in total depth from 8482 to 8850 feet. On the latest completions the equipment used consisted of: "a hydraulic rotary table and snubbers, 3½-in. O.D. 13.3-lb. flush-joint drill pipe, automatic slips, pressure drilling head, small steam-driven water pump for operating the hydraulic table and pull-down yoke, an 8-ft. 500-ton steel substructure and a 12-ft. concrete cellar with heavy anchor lugs."[1] Other surface equipment included: two oil-gas separators, one for 500-lb., the other for 125-lb. pressure, a high-pressure (1200-lb. working pressure) water knockout separator and a recording orifice meter, which was installed on the gas discharge line of the 500-lb. separator. The water knockout separator is used only while drilling in, but may, if necessary, be used as a high-pressure oil-gas separator.

In drilling into the lime, the top of which is at a depth of from 8100 to 8300 ft. a gas zone has to be penetrated the pressure in which is 1900 lb. per sq. inch. This necessitates injecting high-pressure gas into the circulating fluid, which is clear water, at the surface so as to lighten up the fluid column sufficiently to prevent putting a back pressure on the 1900-lb. gas sand and thus keep it alive while drilling through it. The volume of gas injected is maintained within certain limits, depending on the quantity of circulating water discharged by the pump. All circulation returns, consisting of oil, gas, water and cuttings, are separated at the surface and the gas and oil measured. By this means the productivity of the formations penetrated can be measured. The amount of gas injected at the surface into the circulating system depends on the pressure of the formation being penetrated and the volume of gas it produces. In one formation a pressure of 3000-3100 lb. is encountered at about 8500 ft., in which no injected gas is required when the daily flow of gas is 2½ million cu. ft. or greater.

Unconsolidated surface formations underlain by high-pressure gas sands are among the most hazardous conditions encountered in several fields in the Gulf Coast. The danger from blowouts in these fields is very great. One blowout invariably leads to another as a result of the shallow formations having become charged with gas under high-pressure. Drilling under such conditions becomes a difficult and hazardous undertaking. One field in particular, at McFaddin, has been the scene of several blowouts of the character just discussed. Here pressure drilling has been resorted to with some success. Besides controlling the pressure on the circulating system, close attention is paid to the mud fluid. The return lines are equipped with chokes, and pressures can be built up on short notice to control the well should a blowout threaten. Flush-joint drill pipe is being used in this test and the results attained have shown promise of eventually overcoming the blowout hazard entirely.

Hydraulic feed equipment and attachments have been devised for use with or without pressure drilling. Of these there are now on the market, the Hydril and the Sheldon-Burden equipments. These have pioneered the use of hydraulic

[1] "Pressure Completions of Wells in West Texas," by E. V. Foran. A.P.I. Spring Meeting, Southwestern District, Division of Production, Fort Worth, Texas, April 20-21, 1934.

feed equipment the demand for which is gradually increased. The National Supply have recently added a hydraulic feed to their list of drilling equipment. One of these has been in use for almost a year in the Big Lake Field, Texas. The Emsco Derrick and Equipment Co. has also had under rigid tests for some time a hydraulic feed and also pressure-drilling equipment. There are also the "Oweco" drill-pipe feed attachment and the Seamark pressure drilling equipment developed for use in the oilfields of Persia.[2]

For a further discussion of the drilling and control of high-pressure wells and the use of pressure rotary drilling in Persia, the reader is referred a paper by M. C. Seamark.[3]

Power for Drilling

For isolated wildcat locations where fuel and water are scarce the trend is toward the internal combustion engine for power. Multi-Cylinder high-speed Diesel engines in sizes of from 150 to 300 hp. are in use.

On a recent drilling test made with a gas-electric d-c. power drive in the Mid-Continent fields, operating records were carefully compiled and an economic analysis made of the results.[4]

On this well the power units were two 300-hp. engine-driven generator units, each of which consisted of a high-speed multi-cylinder gas engine direct-connected by a flexible coupling to two d-c. generators of different size mounted on the same shaft. This engine and generator assembly was mounted on a common steel skid base. The slush pumps and the drawworks were each driven by a fully protected d-c. hoist motor.[5]

It is brought out in the data obtained from this test that the electric d-c. drive has flexibility closely approaching that of steam power. Full torque can be obtained at all speeds. In a study of down-time in drilling it was found that on five wells closely checked the records show that from 15 to 19 per cent of the time is consumed in pulling out and running in drill pipe.

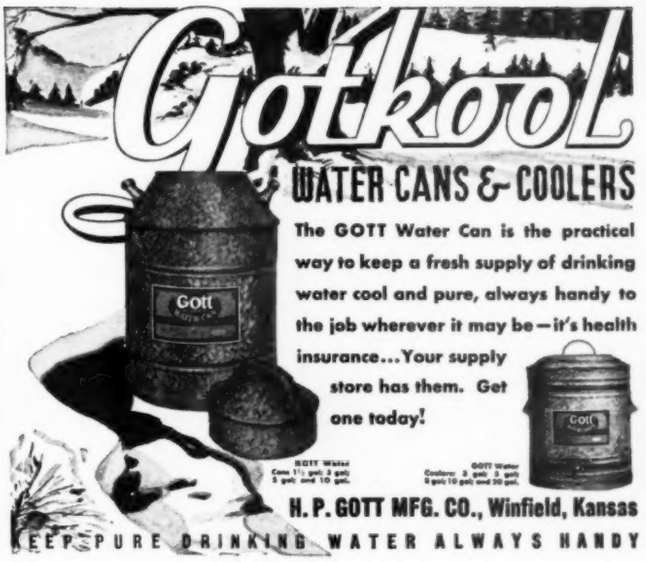
Curves plotted from the data on the torque characteristics of the hoist motor showed that the torque was a maximum at almost zero speed. It is a similar characteristic that makes the steam engine a very desirable power unit for drilling. Maximum torque at low speed is required for pulling a heavy string of drill pipe or landing a heavy string of casing or in fishing jobs or for pulling on a "frozen" string of casing or drill pipe. The electric d-c. drive was also found to be economical in fuel and water consumption and for this reason is well adapted for wildcat drilling operations.

Drill Pipe and Casing

An increase in drilling depth probably places the greatest service demands on drill pipe and casing. A well in the Belridge field, California, has just passed a drilling depth of 11,000 ft., a record that is evidence of not only the improvements that have taken place in modern drilling practice, but also of superior drill pipe materials and manufacture.

In a wildcat well in Crane County, West Texas, drilling is in progress below 10,200 feet. It is being drilled at its present depth with a string of 4½-in. O. D. 16.60-lb. drill pipe. Twenty joints of 6⅝-in. O. D. 77.10 lb. (1⅜-in. wall) A.P.I. Grade D special alloy drill pipe equipped with full-hole tool joints were used for a time in hard formation. The purpose of the heavy pipe on bottom was to increase the rigidity and minimize flexing. All tool joints have been welded as an added precaution to prevent joint

[2] "Pressure Drilling," by B. J. Ellis and James Cuthill. Vol. 1, Proceedings World Petroleum Congress, London, 1933.
[3] "The Drilling and Control of High-Pressure Wells," by M. C. Seamark. Vol. 1, Proceedings, World Petroleum Congress, London, 1933.
[4] "Gas-Electric Prime Movers for Rotary Drilling," by D. M. McCarger and Oscar A. Haas. A.S.M.E. National Petroleum Division Meeting, Tulsa, May 14-17, 1934.
[5] "Direct Current for Rotary Drilling," by W. C. Lane. *The Petroleum Engineer*, June, 1933.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Engineering Review

IN reading this, the fifth annual Engineering Review number of *The Petroleum Engineer*, one is impressed that, although few new engineering practices have been evolved during the past year, the period has been marked by exceptional progress in the development of methods having had their inception previously. Such methods as acidizing wells, electrical pipe line station operation, controlled directional drilling, pressure drilling, etc., have received major consideration and the results of much of the research and many of the tests are recorded in this issue.

As in the past, regular features, such as "The Course of Oil," "Highlights," "Personals," "New Equipment," etc., are omitted from this number only to make room for a maximum amount of review material. They will reappear in the regular June issue.

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leakage and are thoroughly made up and tested before being run in the well. The reason for this is that once the drill pipe has been run in the well and the strain put on a joint it may start to leak, in which case welding the joint would not do any permanent good. Before the use of heavy hydraulic drill pipe on bottom was resorted to on this well serious trouble was experienced that had its inception in bent joints of drill pipe due to flexing. After placing the heavy drill pipe on bottom there was a freedom from failures and steady progress was made even though the drilling conditions were extremely severe.

Attention has been manifest in the use of flush-joint drill pipe and its possibilities for deep drilling in small hole. It has been advocated that flush-joint drill pipe used in combustion with a packer assembly is probably the best system yet devised for the prevention of blow-outs.[6]

The use of flush-joint casing has been suggested for use in drilling to combat a heaving-shale condition. It is quite likely that the trend toward flush-joint casing will increase with the more extended use of pressure drilling.

Mud Fluid

Blowouts in wells in the Gulf Coast fields are known to occur usually when the drill pipe is pulled from the hole. In order to investigate the changes in hydrostatic pressure that take place just below the bit as the drill pipe is withdrawn from the hole a series of tests was made.[7] The results are interesting.

Of the effect of the three properties of mud investigated, gel strength affected the hydrostatic pressure on withdrawal of drill pipe most, viscosity only slightly, and mud weight apparently not at all. The higher the gel strength of the mud the greater was the pressure drop observed. The relation appeared to be roughly as follows: With a gel strength of 3 units (arbitrary units chosen) the pressure drop was 150 lb. per sq. inch; and with mud having a gel strength of 80 units the pressure drop was 385 lb. per sq. inch.

The effect of well depth, rate of withdrawal, drainage from the drill pipe, enlarged drill collar, distance the drill pipe was moved and the annular space, were each investigated in turn.

It was surprising to note that the pressure drop was not appreciably affected by the rate of withdrawal of the drill pipe. Of the remaining factors the only one of importance affecting the hydrostatic pressure was that of well depth. The data obtained indicate that the pressure drop is proportional to the length of drill pipe in the hole.

Gel strength of the mud and the length of drill pipe in the hole seem to be the really important factors that influence the pressure drop when the drill pipe is pulled from the hole. It was also observed that the pressure drops, although of short duration, may be great enough to allow sufficient gas to enter the hole to cause a blowout.

Cementing

Multiple-stage cementing has been used in setting long strings of casing and has reduced many of the hazards of failure attending such operations.

Setting liners in deep wells in sections and cementing off barren strata lying between productive sands has been successfully accomplished in California. A liner was set in the bottom of a well 9143 ft. deep in the Kettleman Hills North Dome. It was 7 in. in diameter and had a total length of 2175 ft. of which 917 ft. was perforated and the rest blank. It was placed in four sections, and four barren strata were successfully cemented off.

Another well in the Kettleman Hills field was completed

[6] "Use of Flush-Joint Drill Pipe and Casing," by W. V. Vietti, A.P.I. Southwestern District Spring Meeting, Division of Production, Fort Worth, Texas, April 20-21, 1934.

[7] "Changes in Hydrostatic Pressure Due to Withdrawing Drill Pipe from the Hole," by George E. Cannon. A.P.I. Southwestern District Spring Meeting, Division of Production, Fort Worth, Texas, April 20-21, 1934.

with a one-piece liner, which was made up of perforated and blank pipe. It had three perforated and three blank sections. Three doubtful strata were successfully cemented off behind the blank sections of the liner.

Coring

Interesting trends in coring practice are the increasing use of electrical coring and wire-line coring in deep wells.

Both the character of the rock and the fluid content of the formation penetrated are determined in electrical coring. The greatest use to which electrical core data have been put so far in the fields of the United States is in making stratigraphic correlations between wells, a purpose for which electrical coring appears to be quite accurate and dependable.

Wire-line coring is well adapted to deep wells where the formations are not extremely hard. There is no need to pull the drill pipe when a core has to be taken. In a 6000-ft. well, for example, a 3-ft. core can usually be taken in an hour and a half's time or even less with the wire-line coring tool. Aside from the saving in time, it is well adapted for use in areas where blowouts are a hazard; there being no need to pull the drill pipe in taking a core, any possibility of a blowout is avoided.

Maritime Drilling

Methods and equipment for drilling shallow wells located in bodies of water so common in the Gulf Coast have undergone rapid development. Derricks and complete drilling equipment installed on barges are readily portable. For drilling shallow wells, where the cost of rigging up may become an exorbitant item, operations have been speeded up and costs reduced.

The construction of the barges and the general layout of equipment are quite a departure from the drilling preparations and layout of equipment generally encountered on land.

The Texas Company has pioneered in the design of complete floating electric power plants for deep drilling. An installation of most recent design consists of two 219-kva. 480-volt 264-amp. 514 r. p. m. Westinghouse generator units, each direct-driven by a 242-hp. Cooper-Bessemer Diesel engine. In use, the barge is moored close by the derrick and power is transmitted by cable to the drilling machinery. Removal of the power plant to another well is usually only a matter of disconnecting the transmission lines, taking up the mooring, and towing the barge to its new location. These units have a low fuel consumption. For both Diesel engines it ranges from 5 to 10 bbl. a day and never has exceeded the upper figure.

Portable Drilling Equipment

Increasing interest is evident in portable rotaries for drilling deep prospect holes. Many companies engaged in wildcatting operations and in testing large structures seem to favor this type of equipment and have very good reasons for doing so. A small hole cannot only be drilled and cored at minimum cost, but it can also be used as a producing well, should oil be found.

Fisher Appoints New Agent

The Fisher Governor Company, Marshalltown, Iowa, manufacturers of automatic control equipment, has announced the appointment, effective June 1, of the Weeks Engineering Company, Harry T. Weeks, manager, 4005 Gravois Avenue, St. Louis, Mo., as factory representative for the St. Louis territory.

Mr. Weeks is well acquainted in the St. Louis area, having covered the industrial accounts there for many years, and is well qualified to handle the Fisher line of controls. He has just returned from the Fisher factory, where he spent several days on the engineering details of Fisher equipment.

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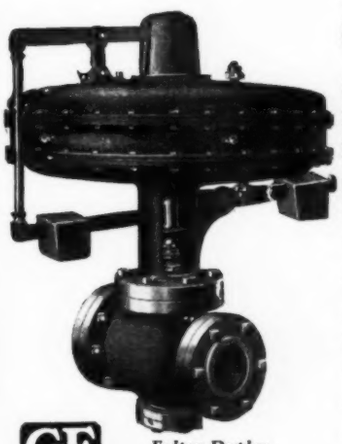

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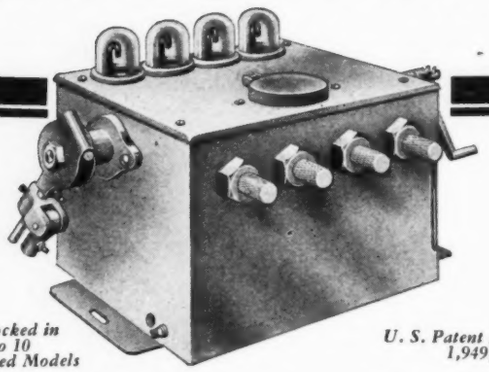

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